QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

1

ATOMIC STRUCTURE AND QUANTUM

GATE 2005

1. The set of eigenfunctions $\sqrt{\frac{2}{1}}\sin\frac{n\pi x}{a}\left(0 \le x \le a, n = 1,2,3...\right)$ is

(a) orthogonal
(b) normalized
(c) both orthogonal and normalized
(d) unnormalized

2. The function e^{ax^2} $\left(\alpha > 0\right)$ is not an acceptable wave function for bound system, because

(a) it is not continuous
(b) it is multivalued
(c) it is not normalisable
(d) all of these

3. First order peturbation correction $\Delta\varepsilon_n^{(1)}$ to energy level ε_n of a simple harmonic oscillator due to the anharmonicity perturbation λx^3 is given by

(a) $\Delta\varepsilon_n^{(1)} = \gamma$
(b) $\Delta\varepsilon_n^{(1)} = \gamma^2$
(c) $\Delta\varepsilon_n^{(1)} = \gamma^{-1}$
(d) $\Delta\varepsilon_n^{(1)} = 0$

4. The 2s orbital of H – atom has radial node at $2a_0$ because ψ_{2s} is proportional to

(a) $\left(\frac{1}{2} + \frac{r}{a_0}\right)$
(b) $\left(2 + \frac{r}{a_0}\right)$
(c) $\left(2 - \frac{r}{a_0}\right)$
(d) $\left(2 - \frac{r}{2a_0}\right)$

5. As per Huckel theory, π – electron energy levels of cyclobutadiene are

(a) $\alpha + 2\beta, \alpha + \beta, \alpha - \beta, \alpha - 2\beta$
(b) $\alpha + 2\beta, \alpha - \beta, \alpha - \beta, \alpha - 2\beta$
(c) $\alpha + 2\beta, \alpha, \alpha, \alpha - 2\beta$
(c) $\alpha + \beta, \alpha - \beta, \alpha - \beta, \alpha - 2\beta$

6. Given that $\beta = -75$ kJ / mol, cyclobutadiene is

(a) paramagnetic and its lowest absorption energy is 150 kJ.
(b) paramagnetic and its lowest absorption energy is 75 kJ.
(c) dimagnetic and its lowest absorption energy is 75 kJ.
(d) diamagnetic and its lowest absorption energy is 150 kJ.

7. The orbital $\psi = ls_{H_A} - ls_{H_B}$ of water belongs to the irreducible representation

(a) A_1
(b) B_1
(c) A_2
(d) B_2

GATE 2006

8. In the Huckle model for benzene, the π electronic transitions from the occupied to the unoccupied molecular orbitals do NOT occur at

(a) 4β (b) 3β (c) 2β (d) 1β

9. To demonstrate the variational principle, a trial function $\psi = C_1 \frac{\psi_{2s} + \psi_{3s}}{\sqrt{2}} + C_2 \frac{\psi_{2s} - \psi_{3s}}{\sqrt{2}}$ where C_1 and C_2 are the variational parameters and ψ_{2s} and ψ_{3s} are the 2s, and 3s orbitals of the hydrogen atom, is constructed. The corresponding secular determinant for the hydrogen atom (in eV) is

(a) $\begin{vmatrix} 3.4(1+4/9)2-E & 3.4(1-4/9)/2 \\ 3.4(1-4/9)/2 & 3.4(1+4/9)2\text{-}E \end{vmatrix}$ (b) $\begin{vmatrix} 3.4(1+4/9)2-E & 3.4(1-4/9)/2 \\ 3.4(1-4/9)/2 & 3.4(1-4/9)2\text{-}E \end{vmatrix}$ (c) $\begin{vmatrix} 3.4(1+4/9)2-E & 3.4(1+4/9)/2 \\ 3.4(1-4/9)/2 & 3.4(1-4/9)2\text{-}E \end{vmatrix}$ (d) $\begin{vmatrix} 3.4(1+4/9)2-E & 0 \\ 0 & 3.4(1+4/9)2\text{-}E \end{vmatrix}$

10. Which of the following pairs of operators commute?

(a) x and $\frac{d}{dx}$ (b) $\frac{d}{dx}$ and $\frac{d^2}{dx^2} + 2\frac{d}{dx}$ (c) $x^2 \frac{d}{dx}$ and $\frac{d^2}{dx^2}$ (d) x^2 and $\frac{d}{dx}$

11. The first excited state wavefunction for a particle in a box that spans from –a to + a is

(a) $\sqrt{\frac{1}{a}} \cos\left(\frac{\pi x}{a}\right)$ (b) $\sqrt{\frac{1}{a}} \sin\left(\frac{\pi x}{a}\right)$ (c) $\sqrt{\frac{2}{a}} \cos\left(\frac{2\pi x}{a}\right)$ (d) $\sqrt{\frac{2}{a}} \sin\left(\frac{2\pi x}{a}\right)$

12. A perturbation $V = \delta(x - a/2)$ is introduced in the box. The first order energy correction to the first excited state is.

(a) 0 (b) 2/a (c) 1/a (d) 1/2a

GATE 2007

13. The dimension of Planck constant is (M, L and T denote mass, length and time respectively)

(a) ML^3T^{-2} (b) ML^3T^{-1} (c) $M^2L^{-1}T^{-1}$ (d) $M^{-1}L^2T^{-2}$

14. For a homonuclear diatomic molecule, the bonding molecular orbital is

(a) σ_u of lowest energy (b) σ_u of second lowest energy

(c) π_g of lowest energy (d) π_u of lowest energy

15. The ionisation potential of hydrogen atom is 13.6 eV. The first ionisation potential of a sodium atom, assuming that the energy of its outer electron can be represented by a H – atom like model with an effective nuclear charge of 1.84, is

(a) 46.0 eV (b) 11.5 eV (c) 5.1 eV (d) 2.9 eV

16. The quantum state of a particle moving in a circular path in a plane is given by

$$\psi_m(\phi) = \left(1/\sqrt{2\pi}\right)e^{im\phi}, m = 0, \pm 1, \pm 2, ...$$

When a perturbation $H_1 = P\cos\phi$ is applied (P is a constant), what will be the first order correction to the energy of the m^th^ state

(a) 0 (b) $P/(2\pi)$ (c) $P/(4\pi)$ (d) $Pm^2/(4\pi^2)$

17. Consider a particle of mass m moving in a one – dimensional box under the potential $V = 0$ for $0 \le x \le a$ and $V = \infty$ outside the box. When the particle is in its lowest energy state the average momentum ($< p_x >$ of the particle is

(a) $< p_x >= 0$ (b) $< p_x >= \frac{h}{a}$ (c) $< p_x >= \frac{h}{2a}$ (d) $< p_x >= \frac{h}{2\pi a}$

18. The uncertainty in the momentum (Δp_s) of the particle in its lowest energy state is:

(a) $\Delta p_x = 0$ (b) $\Delta p_x = \frac{h}{a}$ (c) $\Delta p_x = \frac{h}{2a}$ (d) $\Delta p_x = \frac{h}{2\pi a}$

GATE 2008

19. The lifetime of a molecule in an excited electronic state is 10^{-10} s. The uncertainty in the energy (eV) approximately is

(a) 2×10^{-5} (b) 3×10^{-6} (c) 0 (d) 10^{-14}

20. The wavefunction of a diatomic molecule has the form $\psi = 0.89\phi_{convalent} + 0.45\phi_{ionic}$. The chance that both electrons of the bond will be found on the same atom in 100 inspections of teh molecule approximately is

(a) 79 (b) 20 (c) 45 (d) 60

21. The ground state electronic energy (Hartree) of a helium atom, neglecting the inter – electron repulsion, is

(a) –1.0 (b) –0.5 (c) –2.0 (d) –4.0

22. A particle is confined to a one – dimensional box of length 1 mm. If the length is changed by 10^{-9} m, the % change in the ground state energy is

(a) 2×10^{-4} (b) 2×10^{-7} (c) 2×10^{-2} (d) 0

23. The operation of the commutator $[x, d/dx]$ on a function f(x) is equal to

(a) 0 (b) f(x) (c) –f(x) (d) x df/dx

24. The de – Broglie wavelength of the electron is $\frac{\lambda}{pm} = \left(\frac{a}{\varphi}\right)^{1/2}$. The value of 'a' in volts is

(a) 1.5×10^{-18} (b) 1.5×10^{6} (c) 6.63×10^{-5} (d) 2.5×10^{18}

GATE 2009

25. The lowest allowed energy is eual to zero for

(a) the hydrogen atom

(b) a rigid rotor

(c) a harmonic oscillator

(d) a particle in a 3-dimensional box

26. The degeneracy of a quantum particle in a cubic box having energy four times that of the lowest energy is

(a) 3 (b) 6 (c) 1 (d) 4

27. The de-Broglie wavelength for a He atom travelling at 1000 ms^{-1} (typical speed at room temperature) is

(a) 99.7×10^{-12}m (b) 199.4×10^{-12}m (c) 199.4×10^{-18}m (d) 99×10^{-6}m

GATE 2010

28. For eigen functions $\psi_1 = \sqrt{\frac{1}{b}}\sin\left(\frac{\pi x}{b}\right)$ and $\psi_2 = \sqrt{\frac{2}{b}}\sin\left(\frac{2\pi x}{b}\right)$ os particle in a 1 – D box of length $b\left(0 \le x \le b\right)$

(a) ψ_1 is normalized but not orthogonal to ψ_2

(b) ψ_2 is normalized but not orthogonal to ψ_1

(c) ψ_2 is normalized and orthogonal to ψ_1

(d) ψ_2 is neither normalized nor orthogonal to ψ_1

29. The commutator $\left[x^3, p_x\right]$ is equal to

(a) $-\frac{3hx^2}{2\pi i}$ (b) $\frac{hx}{2\pi i}$ (c) $\frac{hx^2}{2\pi i}$ (d) $\frac{3hx^2}{2\pi i}$

30. An electron of mass 'm' is confined to a one dimensional box of length 'b'. If it makes a radiative transition from second excited state to the ground state, the frequency of the photon emitted is

(a) $\frac{9h}{8mb^2}$ (b) $\frac{3h}{8mb^2}$ (c) $\frac{h}{mb^2}$ (d) $\frac{2h}{mb^2}$

GATE 2011

31. The wave function for a harmonic oscillator described by $Nx\exp(-\alpha x^2/2)$ has

(a) One maximum only

(b) One maximum, one minimum only

(c) Two maxima, one minimum only

(d) Two maxima, two minima only

32. If an arbitrary wave function is used to calculate the energy of a quantum mechanical system, the value calculated is never less than the true energy.

The above statement relates to

(a) Perturbation theory

(b) Variation principle

(c) Heisenberg's uncertainty principle

(d) quantization of energy

33. The wave function for a quantum mechanical particle in a 1-dimensional box of length 'a' is given by $\psi = A\sin\frac{\pi x}{a}$

The value of 'A' for a box of length 200 nm is

(a) $4 \times 10^4\ (\text{nm})^2$ (b) $10\sqrt{2}\left(\text{nm}\right)^{1/2}$ (c) $\sqrt{2}/10\left(\text{nm}\right)^{-1/2}$ (d) $0.1\ (\text{nm})^{-1/2}$

GATE 2012

34. If Δy and ΔP_y are the uncertainties in the y – coordinate and the y component of the momentum of a particle respectively, then, according to uncertainty principle $\Delta y \Delta P_y$ is:

$$\left(\hbar = \frac{h}{2\pi} \text{ and h is Planck's constant}\right)$$

(a) $\geq \hbar$ (b) $> \hbar/2$ (c) $> \hbar$ (d) $\geq \hbar/2$

35. Choose the allowed transition

(a) ${}^1\Sigma_g^+ \to {}^3\Sigma_u^+$ (b) ${}^1\Sigma_g^+ \to {}^3\Sigma_u^-$ (c) ${}^1\Sigma_g^+ \to {}^1\Sigma_u^+$ (d) ${}^1\Sigma_g^+ \to {}^1\Sigma_u^-$

36. The angular part of the wavefunction for the electron in hydrogen atom is proportional to $\sin^2\theta\cos\theta\, e^{2i\phi}$. The values of the azimuthal quantum number *l* and the magnetic quantum number (m) are respectively.

(a) 2 and 2 (b) 2 and – 2 (c) 3 and 2 (d) 3 and – 2

37. Let ϕ_x^C and ϕ_z^C denote the wavefunctions of the $2p_x$ and $2p_z$ orbitals of carbon, respectively, and ϕ_x^C and ϕ_z^0 represent the wavefunction of the $2p_x$ and $2p_z$ orbitals of oxygen, respectively. If c_1 and c_2 are constants used in linear combinations and the CO molecule is oriented along the z axis than, according to molecular orbital theory, the π – bonding molecular orbital has a wavefunction given by

(a) $c_1\phi_z^C + c_2\phi_x^0$ (b) $c_1\phi_z^C + c_2\phi_z^0$ (c) $c_1\phi_x^C + c_2\phi_z^0$ (d) $c_1\phi_x^C + c_2\phi_x^0$

38. The wavefunction of a 1 – D harmonic oscillator between $x = +\infty$ and $x = -\infty$ is given by $\psi(x) = N(2x^2 - 1)e^{-x^2/2}$. The value of N that normalizes the function $\psi(x)$ is:

$$\left(\text{Given} \int_{-\infty}^{+\infty} x^{2n} e^{-x^2} dx = \frac{1.35...(2n-1)}{2^n}\sqrt{\pi}\right)$$

(a) $\left(\frac{1}{8\sqrt{\pi}}\right)^{\frac{1}{2}}$ (b) $\left(\frac{1}{3\sqrt{\pi}}\right)^{\frac{1}{2}}$ (c) $\left(\frac{1}{2\sqrt{\pi}}\right)^{\frac{1}{2}}$ (d) $\left(\frac{1}{4\sqrt{\pi}}\right)^{\frac{1}{2}}$

39. The secular determinant (where α, β and E have their usual meanings) is given by

(a) $\begin{vmatrix} \alpha - E & \beta & 0 \\ \beta & \alpha - E & \beta \\ 0 & \beta & \alpha - E \end{vmatrix}$ (b) $\begin{vmatrix} \alpha - E & 0 & 0 \\ 0 & \alpha - E & \beta \\ 0 & \beta & \alpha - E \end{vmatrix}$

(c) $\begin{vmatrix} \alpha - E & 0 & 0 \\ \beta & \alpha - E & 0 \\ 0 & 0 & \alpha - E \end{vmatrix}$ (d) $\begin{vmatrix} \alpha - E & -\beta & 0 \\ -\beta & \alpha - E & -\beta \\ 0 & -\beta & \alpha - E \end{vmatrix}$

40. The possible value of E are

(a) $\alpha + \sqrt{2}\beta, \alpha, \alpha - \sqrt{2}\beta$ (b) $\alpha + 2\sqrt{2}\beta, \alpha, \alpha - 2\sqrt{2}\beta$

(c) $\alpha + \beta, \alpha, \alpha - \beta$ (d) $\alpha + 2\beta, \alpha, \alpha - 2\beta$

GATE 2013

41. Two trial wave function $\phi = c_1x(a-x)$ and $\phi_2 = c_1x(a-x)+c_2x^2(a-x)^2$ give ground state energies E_1 and E_2, respectively, for the microscopic particle in a 1 – D box by using the variation method. If the exact ground state energy is E_0, the correct relationship between E_0, E_1 and E_2 is:

(a) $E_0 = E_1 = E_2$ (b) $E_0 < E_1 < E_2$ (c) $E_0 < E_2 < E_1$ (d) $E_0 > E_2 = E_1$

42. The ground state energies of H atom and H_2 molecule –13.6 eV and –31.7 eV, respectively. The dissociation energy of H_2 is ___________ eV.

43. e^{-2x^2} is an eigen function on the operator $\left(\frac{d^2}{dx^2}-16x^2\right)$. The corresponding eigen value is

(a) +4 (b) –4 (c) + 2 (d) –2

GATE 2014

44. The value of the magnetic quantum number of a p_x orbital is

(a) –1 (b) 0 (c) +1 (d) undefined

45. Suppose ψ_1 and ψ_2, are two hybrid orbitals:

$\psi_1 = 0.12\psi_{3s} + 0.63\psi_{3p_x} + 0.77\psi_{3p_y}$ and $\psi_2 = 0.12\psi l3s - 0.63\psi_{3p_x} - 0.77\psi_{3p_y}$

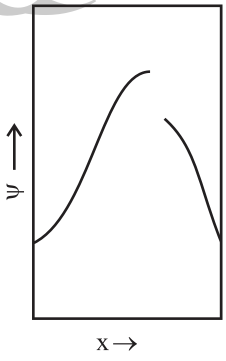
The angle (in degrees) between them is ________

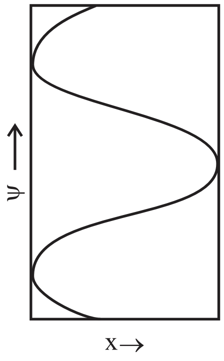
GATE 2015

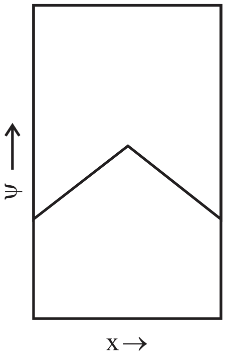
46. When the operator, $-\hbar^2 d^2/dx^2$, operates on the function e^{-kx}, the result is

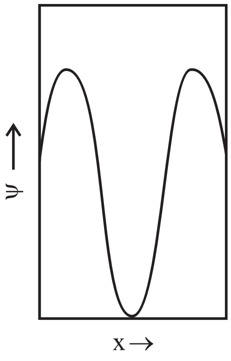
(a) $k^2\hbar^2 e^{-ikx}$ (b) $ik^2\hbar^2 e^{-ikx}$ (c) $i\hbar^2 e^{-ikx}$ (d) $\hbar^2 e^{-ikx}$

47. Which one of the following plots represents an acceptable wavefunction?

(a)


(b)


(c)


(d)


48. The difference in the ground state energies (kJ/mol) of an electron in one-dimensional boxes of lengths 0.2 nm and 2nm is _________.

GATE 2016

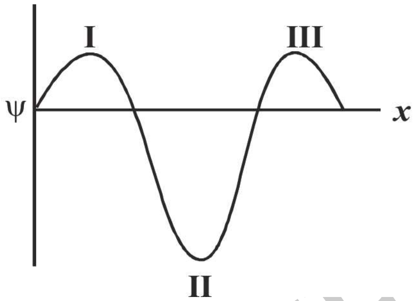
49. The linear momentum of a particle described by the wavefunction e^{-ikx} is

(a) kh (b) –kh (c) $k\hbar$ (d) $-k\hbar$

50. The experimental ionization energies of hydrogen and helium atoms in their ground states are, respectively, 13.6 eV and 24.6 eV. The ground state energy of helium atom, in eV, is

(a) $-\frac{1}{2}(13.6)-24.6$ (b) $-4(13.6)-24.6$ (c) $-\frac{1}{4}(13.6)-24.6$ (d) $-2(13.6)-24.6$

51. A system is described by the following real wavefunction.



The probability (P) of finding the particle in a region dx around points I, II and III in the figure obeys the trend

(a) P(I) > P(II) > P(III) (b) P(II) > P(III) > P(I)

(c) P(II) > P(I) > P(III) (d) P(III) > P(I) > P(II)

GATE 2017

52. For ortho – hydrogen, the nuclear wavefunction and the rotational quantum number, respectively, are

(a) antisymmetric and even

(b) symmetric and odd

(c) symmetric and even

(d) antisymmetric and odd

53. The wavelength associated with a particle in one – dimensional box of length L is (n referes to the quantum number)

(a) 2L / n (b) L / n (c) nL (d) L/2n

54. The lowest energyof a quantum mechanical one – dimensional simple harmonic oscillator is 300 cm^{-1}. The energy (in cm^{-1}) of the next higher level is +_________

55. Assume 1, 3, 5 – hexatriene to be a linear molecule and model the π electrons as particles in a one – dimensional box of length 0.70 nm. The wavelength (in nm) corresponding to the transition from the ground – state to the first excited – state is _______________.

56. The angle of orientation (in degrees) of the angular momentum vector with respect to z – axis for I = 2 and $m_\ell = +2$ state of H – atom is _________ (up to two decimal places)

57. $\Psi = \left[c\phi_1 - \left(1-\sqrt{3}\right)\phi_2\right]$ represents a normalized molecular orbital constructed from two different atomic orbitals ϕ_1 and ϕ_2 that form an orthonormal set. The value of |c| is __________. (up to two decimal places)

GATE 2018

58. The spherical harmonic function $Y_{\ell,m}(\theta,\phi)$ with appropriate values of ℓ and m, is an eigenfunction of $\hat{L}_x^2+\hat{L}_y^2$ operator. The corresponding eigenvalue is

(a) $\left(\ell(\ell+1)-m^2\right)\hbar^2$ (b) $\left(\ell(\ell+1)+m^2\right)\hbar^2$

(c) $\ell(\ell+1)\hbar^2$ (d) $m^2\hbar^2$

59. Consider the operators, $\hat{a}_+=\frac{1}{\sqrt{2}}\left(\hat{x}+\hat{i}p_x\right)$ and $\hat{a}_-=\frac{1}{\sqrt{2}}\left(\hat{x}-\hat{i}p_x\right)$, where $\hat{x}$ and $\hat{p}_x$ are the position and linear momentum operators, respectively. The commutator, $\left[\hat{a}_+,\hat{a}_-\right]$ is equal to

(a) $i\hbar$ (b) $-i\hbar$ (c) $\hbar$ (d) $-\hbar$

60. The enrgy of a hydrogen molecule in its ground state equilbrium configuration is –31.7eV. Its dissociation energy is ______________eV. (Upto one decimal place)

61. In a molecule XY, let ψ_X and ψ_Y denote normalized atomic orbitals of atoms X and Y, respectively. A normalized molecular orbital of XY is given by $\psi_+=0.56(\psi_X+\psi_Y)$. The value of the overlap integral of ψ_X and ψ_Y is ___________ (Upto two decimal place)

62. At temperature T, the canonical partition function of a harmonic oscillator with fundamental frequency (v) is given by

$$q_{vib}(T)\frac{e^{-hv/2k_BT}}{1-e^{-hv/k_BT}}$$

For $\frac{hv}{k_BT}=3$, the probability of finding the harmonic oscillation in its ground vibrational state is ___________ (Upto two decimal places)

63. A one-dimensional anharmonic oscillator is treated by perturbation theory. The harmonic oscillator is used as the unperturbed system and the perturbation is $\frac{1}{6}\gamma x^3$ (γ is a constant). Using only the first order correction, the total ground state energy of the anharmonic oscillator is

Note: For aone-dimensional harmonic oscillator $\psi_0(x)=\left(\frac{\alpha}{\pi}\right)^{1/4}e^{-\alpha x^2};\alpha=\left(\frac{k\mu}{h^2}\right)^{1.2}$

(a) $\frac{1}{2}\hbar\left(\frac{k}{\mu}\right)^{1/2}$ (b) $\left(\frac{1}{2}+\frac{\gamma}{6}\right)\hbar\left(\frac{k}{\mu}\right)^{1/2}$ (c) $\left(\frac{1}{2}+\frac{\gamma}{3}\right)\hbar\left(\frac{k}{\mu}\right)^{1/2}$ (d) $\left(\frac{1}{2}+\frac{\gamma}{12}\right)\hbar\left(\frac{k}{\mu}\right)^{1/2}$

64. The π electrons in benzene can be modelled as particles in a ring that follow Pauli's exclusion principle. Given that the radius of benzene is 1.4Å, the longest wavelength of light that is absorbed during an electronic transition in benzene is ________________________________nm. (Upto one decimal place. Use $m_e=9.1\times10^{-31}$kg, h = 6.6×10^{-34}Js, c = 3.0×10^8 ms^{-1})

GATE 2019

65. Suppose the wave function of a one dimensional system is

$$\psi = \sin(kx)\exp(3ikx)$$

In an experiment measuring the momentum of the system, one of the expected outcomes is

(a) 0 (b) $\hbar k$ (c) $2\hbar k$ (d) $3\hbar k$

66. A particle in one dimensional box of length 2a with potential energy

$$V = \begin{cases} 0 & |x| < a \\ \infty & |x| > a \end{cases}$$

is perturbed by the potential $V' = cx$ eV, where c is a constant. The 1st order correction to the 1st excited state of the system is _________ × c eV.

67. If $\langle \alpha | \hat{S}_x\hat{S}_y - \hat{S}_y\hat{S}_x | \alpha \rangle = i\hbar^2 a$, where $\hat{S}_x$ and $\hat{S}_y$ are spin angular momentum operators and $|\alpha\rangle$ is spin up eigen function, then the value of 'a' is __________. (Round off to one decimal place)

68. Consider a two dimensional harmonic oscillator with angular frequency $\omega_x = 2\omega_y = 6.5 \times 10^{14}$ rad s^{-1}. The wavelength of x polarized light required for the excitation of a particle from its ground state to the next allowed excited state is _______ × 10^{-6} m. (Round off to one dimensional place)

(Speed of light $c = 3.0 \times 10^8$ m s^{-1})

GATE 2020

69. Among the following linear combination of atomic orbitals, the CORRECT representation of the lowest unoccupied π-molecular orbital of butadiene is:

(a) $\Psi = 0.602\,\phi_1 - 0.372\,\phi_2 - 0.372\,\phi_3 + 0.602\,\phi_4$

(b) $\Psi = -0.372\,\phi_1 + 0.602\,\phi_2 - 0.602\,\phi_3 + 0.372\,\phi_4$

(c) $\Psi = 0.602\,\phi_1 + 0.372\,\phi_2 - 0.372\,\phi_3 - 0.602\,\phi_4$

(d) $\Psi = 0.372\,\phi_1 + 0.602\,\phi_2 + 0.602\,\phi_3 + 0.372\,\phi_4$

70. The hydrogen-like radial wave function of the 3s orbital is given as

$$R_{3,0} = \frac{1}{9\sqrt{3}}\left(\frac{Z}{a_0}\right)^{3/2}\left(6 - 2p + \frac{\rho^2}{9}\right)e^{-\rho/6}$$

where $\rho = 2Zr/a_0$; Z = atomic number; r = distance from the nucleus and a_0 = Bohr radius.

Positions of the radial nodes (in units of α_0) of the 3s orbital are at

(a) $\frac{3+3\sqrt{3}}{2Z}, \frac{3-3\sqrt{3}}{2Z}$ (b) $\frac{9+3\sqrt{3}}{2Z}, \frac{9-3\sqrt{3}}{2Z}$

(c) $\frac{3+\sqrt{3}}{2Z}, \frac{3-\sqrt{3}}{2Z}$ (d) $\frac{6+3\sqrt{3}}{2Z}, \frac{6-3\sqrt{3}}{2Z}$

71. The % error (rounded off to two decimal places) in the ground state energy of a particle in a one dimensional box of length 'a' described by a trial variation function $\varphi = x(a-x)$, where $0 \le x \le a$, is ______

(Given: The true ground state energy of the above system is $h^2/8ma^2$; $\int_0^a \varphi^* \varphi d\tau = a^5/30$)

GATE 2021

72. The de Broglie wavelength of an argon atom (mass = 40 amu) traveling at a speed of 250 m s^{-1} (rounded off to one decmial place) is _______ picometers.

[N = 6.022×10^{23}; h = 6.626×10^{-34} kg m^2 s^{-1}]

73. Acceptable wavefunction for a quantum particle must be;

(a) even (b) single – valued (c) odd (d) continuous

ATOMIC STRUCTURE AND QUANTUM

ANSWER KEY

1.	(c)	2.	(c)	3.	(d)	4.	(c)	5.	(a)	6.	(b)	7.	(b)
8.	(d)	9.	(a)	10.	(?)	11.	(b)	12.	(c)	13.	(b)	14.	(d)
15.	(c)	16.	(a)	17.	(a)	18.	(c)	19.	(b)	20.	(b)	21.	(c)
22.	(a)	23.	(c)	24.	(b)	25.	(b)	26.	(c)	27.	(a)	28.	(c)
29.	(?)	30.	(c)	31.	(b)	32.	(b)	33.	(d)	34.	(d)	35.	(c)
36.	(c)	37.	(d)	38.	(c)	39.	(a)	40.	(a)	41.	(c)	42.	(4.5)
43.	(b)	44.	(d)	45.	(179)	46.	(a)	47.	(d)	48.	(896 to 900)		
49.	(d)	50.	(b)	51.	(b)	52.	(b)	53.	(a)	54.	(900)		
55.	(225 or240)			56.	(33.60 to 36.90)			57.	(0.81)	58.	(a)	59.	(c)
60.	(4.5)	61.	$\{S_{XY} = 0.59\}$										
62.	(0.95)	63.	(a)	64.	$(\lambda = 212.1\text{ nm})$			65.	$(\langle P \rangle = 3\hbar k)$		66.	(0)	
67.	(0.5)	68.	$(\lambda = 2.9\times10^{-6}\text{m})$			69.	(a)	70.	(c)	71.	(1.32)	72.	(=40 pm)
73.	(b,d)												

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

2

THERMODYNAMICS AND THERMOCHEMISTRY

GATE 2005

1. In an adiabatic system, the work done to change its state from A to B is
(a) dependent on path from A to B
(b) independent of path from A to B
(c) path dependence is related to particulars of state A and B
(d) path dependence is related to both states A and B and choice of path

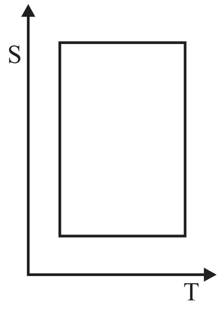
2. The internal pressure, $\pi_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$ for one mole a Vander waals gas is
(a) $\frac{a}{V^2}$ (b) $\frac{a}{V^2}\left(\frac{RT}{V-b}\right)$ (c) Zero (d) $\frac{RT}{V-b}$

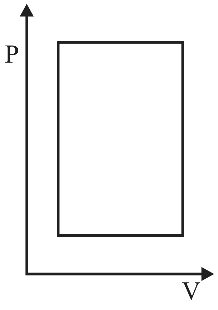
3. Standard entropy of crystalline carbon monoxide (in J/mol) at 0 K is around
(a) 0.03 (b) 2.50 (c) Zero (d) 5.76

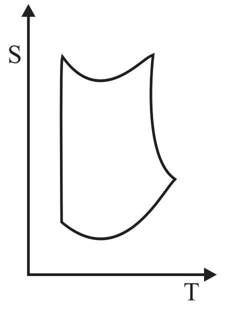
4. Hydrogen adsorption on a platinum surface is
(a) Endothermic with positive ΔS and positive ΔG
(b) Endothermic with positive ΔS and negative ΔG
(c) Exothermic with negative ΔS and negative ΔG
(d) Exothermic with positive ΔS and negative ΔG

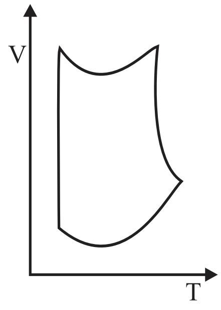
GATE 2006

5. The plot that describes a Carnot cycle is:

(a)


(b)


(c)


(d)


6. ΔS^0_{univ} for the following reaction, at 298 K is:

$N_2 + 3H_2 \rightarrow 2NH_3$ $\Delta S^0_{sys} = -197 JK^{-1}$, $\Delta H^0_{sys} = -91.8 kJ$

(a) -197 J K^{-1} (b) 0 J K^{-1} (c) -308 J K^{-1} (d) 111 J K^{-1}

7. The work done (in atm-L) on the gas in the process is

(a) 9.5 (b) 99.75 (c) 190 (d) 10 ln (20)

8. For the above process,

(a) $\Delta H = W$ (b) $\Delta H = Q$ (c) $\Delta H = \Delta G$ (d)

GATE 2007

9. The expression which represents the chemical potential of the ith sp species (μ_i) in a mixture $(i \neq j)$ is

(a) $(\partial E / \partial n_i)_{s,v,nj}$ (b) $(\partial H / \partial n_i)_{s,v,nj}$ (c) $(\partial A / \partial n_i)_{s,v,nj}$ (d) $(\partial G / \partial n_i)_{s,v,nj}$

10. The temperature of 54 g of water is raised from 15ºC to 75ºC at constant pressure. The change in the enthalpy of the system (given that $C_{p.m}$ of water = 75 $JK^{-1}mol^{-1}$) is:

(a) 4.5 kJ (b) 13.5 kJ (c) 9.0 kJ (d) 18.0 kJ

11. The specific volume of liquid water is 1.001 mL g^{-1} and that of ice is 1.0907 mL g^{-1} at ºC. If the heat of fusion of ice at this temperature is 333.88 J g^{-1}, the rate of change of melting point of ice with pressure in deg atm^{-1} will be

(a) –0.0075 (b) 0.0075 (c) 0.075 (d) –0.075

12. The entropy of mixing of 10 moles of 10 moles of helium and 10 moles of oxygen at constant temperature and pressure, assuming both to be ideal gas, is:

(a) 115.3 JK^{-1} (b) 5.8 Jk^{-1} (c) 382.9 JK^{-1} (d) 230.6 JK^{-1}

13. The correct statement (s) among the following is/are

(i) The vibrational energy levels of a real diatomic molecule are equally spaced.

(ii) At 500K, the reaction $A \rightarrow B$ is spontaneous when $\Delta H = 18.83$ kJ mol^{-1} and $\Delta S = 41.84$ J K^{-1} mol^{-1}.

(iii) The process of fluorescence involves transition from a singlet electronc state to another singlet electronic state by absoprtion of light.

(iv) When a constant P is added to each of the possible energies of a system, its entropy remains unchanged.

(a) Only i (b) Only ii (c) Both i and iii (d) Both ii and iv

GATE 2008

14. The residual entropy of the asymmetric molecule N_2O in its crystalline state is 5.8 J K^{-1} mol^{-1} at absolute zero. The number of orientations that can be adopted by N_2O in its crystalline state is

(a) 4 (b) 3 (c) 2 (d) 1

15. If a gas obeys the equation of state $P(V - nb) = nRT$, the ratio $\dfrac{(C_P - C_V)}{(C_P - C_v)_{ideal}}$ is:

(a) >1 (b) <1 (c) 1 (d) (1 – b)

GATE 2009

16. Among the following the system that would require the least amount of thermal energy to bring its temperature to 80ºC.

(a) 200 gm fo water at 40° (b) 100 gm of water at 20°C

(c) 150 gm of water at 50°C (d) 300 gm of water at 30°C.

17. Among the following, the reaction that is accompanied by a decrease in the entropy is

(a) $N_2(g)+3H_2(g)\rightarrow 2NH_3(g)$ (b) $C_6H_{12}O_6(s)+6O_2(g)\rightarrow 6CO_2(g)+6H_2O(l)$

(c) $PCl_5(s)\rightarrow PCl_3(l)+Cl_2(g)$ (d) $2H_2O(l)\rightarrow 2H_2(g)+O_2(g)$

18. Given that the standard molar enthapies of formation of NO(g) and NO_2 (g) are, respectively, 90.3 kJ mol^{-1} and 33.2 kJ mol^{-1}, the enthalpy change for the reaction 2NO(g) + O_2 (g) (g) $\rightarrow$ $2NP_2$ (g) is

(a) 16.6 kJ (b) –57.1 kJ (c) –114.2 kJ (d) 57.1 kJ

19. The free energy change (ΔG) of 1 mole of an ideal gas that is compressed isothermally from 1 atm to 2 atm is:

(a) RTln2 (b) –2RT (c) –RTln2 (d) 2RT

GATE 2010

20. The molar entropy of crystalline CO at absolute zero is

(a) Zero (b) –Rln 2 (c) Rln 2 (d) 2Rln 2

21. For an ideal gas

(a) $\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial T}{\partial V}\right)_P\left(\frac{\partial V}{\partial P}\right)_T=0$ (b) $\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial T}{\partial V}\right)_P\left(\frac{\partial V}{\partial P}\right)_T=-1$

(c) $\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial T}{\partial V}\right)_P\left(\frac{\partial V}{\partial P}\right)_T=+1$ (d) $\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial T}{\partial V}\right)_P\left(\frac{\partial V}{\partial P}\right)_T=+2$

22. Among W (work), Q (heat), U (internal energy) and S (entropy)

(a) W and U are path functions but Q and S are state functions.

(b) W and S are path functions but Q and U are state functions.

(c) S and Uare path functions but Q and W are state functions.

(d) W and Q are path functions but U and S are state functions.

23. The change in entropy when two moles of Argon gas are heated at constant volume from 300 K to 500 K is:

(a) –12.74 J K^{-1} $mole^{-1}$ (b) – 6.37 J K^{-1} $mole^{-1}$

(c) 6.37 J K^{-1} $mole^{-1}$ (d) 12.74 J K^{-1} $mole^{-1}$

24. At any temperature T, fugacity coefficient (γ) is given by

$$\text{In}\ \gamma=\int_0^P\frac{Z-1}{P'}dP'$$

where Z is the compressibility factor. The fugacity coefficient of a real gas governed by equations of state, P (V – b) = RT with'b' a constant is given by

(a) $\frac{RT}{bP}$ (b) $e^{\frac{RT}{bP}}$ (c) $\frac{bP}{RT}$ (d) $e^{\frac{bP}{RT}}$

25. Based on the above diagram.

(a) A represents the change in chemical potential as a function of temperature for the solid phase, B for the liquid and C for the gas.

(b) A represents the change in chemical potential as a function of temperature for the gas phase, B for the gas and C for the soild.

(c) A represents the change in chemical potential as a function of temperature the liquid phase, B for the gas and C for the solid.

(d) A represent the change in chemical potential as a function of temperature for the gas phase, B for the gas and C for the liquid.

GATE 2011

26. $\left(\frac{\partial G}{\partial P}\right)_T =$

(a) V (b) S (c) –S (d) –V

27. For the process

$$1\ \text{Ar}(300\text{K}, 1\ \text{bar}) \longrightarrow 1\ \text{Ar}(200\text{K}, 10\ \text{bar})$$

assuming ideal gas behavior, the change in molar entropy is:

(a) –27.57 J K^{-1} mol^{-1} (b) +27.57 JK^{-1} mol^{-1} (c) –24.20JK^{-1} mol^{-1} (d) +24.20 JK^{-1} mol^{-1}

GATE 2013

28. For the reaction $X_2O_4(\ell) \rightarrow 2XO_2(g)$ at 298 K, given the values, $\Delta U = 9$ kJ and $\Delta S = 84$ J K^{-1}, ΔG is

(a) –11.08 kJ (b) + 11.08 kJ (c) – 13.55 kJ (d) + 13.55 kJ

29. The change in enthalpy when 3 mol of liquid benzene transforms to the vapour state at its boiling temperature (80ºC) and at 1 bar pressure is ____________ kJ.

GATE 2014

30. The maximum non-PV work that a system can perform at constant P is

(a) ΔH (b) ΔG (c) ΔS (d) ΔA

31. Consider the reaction:

$$A + B \rightleftharpoons C$$

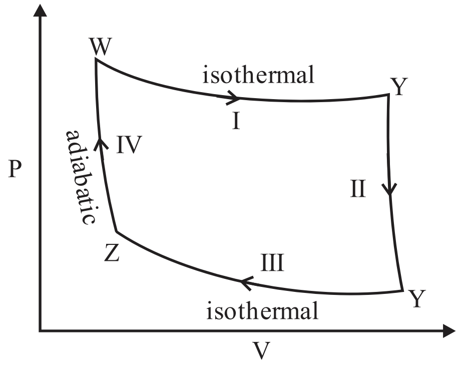
The unit of the thermodynamic equilibrium constant for the reaction is

(a) mol L^{-1} (b) L mol^{-1} (c) mol^2 L^{-2} (d) dimensionless

32. A Carnot engine operates at 55% efficiency. If the temperature of reject steam is 105ºC, then the absolute temperature of input steam is __________

GATE 2015

33.



From the above Carnot cycle undergone by an ideal gas, identify the processes in which the change in internal enery is **NON-ZERO**.

(a) I and II (b) II and IV (c) II and III (d) I and IV

34. Which one of the following defines the absolute temperature of a system?

(a) $\left(\frac{\partial U}{\partial S}\right)_v$ (b) $\left(\frac{\partial A}{\partial S}\right)_v$ (c) $\left(\frac{\partial H}{\partial S}\right)_v$ (d) $\left(\frac{\partial G}{\partial S}\right)_v$

35. The internal energy of an ideal gas follows the equation U = 3.5 PV + k, where k is a constant. The gas expands from an initial volume of 0.25 m^3 to a final volume of 0.86 m^3. If the initial pressure is 5 N m^{-2}, the change in internal energy (in joules) is (given $PV^{1.3}$ = constant) _________.

36. One mole of a substance is heated from 300K to 400K at contant pressure. The C_p of the substance is given by, C_p (JK^{-1} mol^{-1}) = 5 + 0.1T. The change in entropy, in JK^{-1} mol^{-1}, of the sustance is _________.

GATE 2016

37. One mole of an ideal gas is comlpressed from 5L to 2L at constant temperature. The change in entropy, in JK^{-1}, of the gas is ____________. (R = 8.314 JK^{-1} mol^{-1})

38. Of the following inequalities, the criteria for spontaneity of a chemical reaction is/are

(i) $(\Delta G)_{T,P} < 0$ (ii) $(\Delta U)_{S,V} > 0$ (iii) $(\Delta S)_{U,V} > 0$

(a) (i) only (b) (ii) only (c) (i) and (ii) (d) (i) and (iii)

39. At 1 bar and 298K, for the process $A(s) \rightarrow A(\ell)$, the ΔG is 200 J mol^{-1} and ΔV_m is -2×10^{-6} m^3 mol^{-1}. The minimum pressure, in bar, at which the process becomes spontaneous at 298K is _______. (1 bar = 10^5 Pa).

40. For a system subjected to only P-V work, entropy is given by

(I) $-\left(\frac{\partial G}{\partial T}\right)_P$ (II) $\left(\frac{\partial G}{\partial P}\right)_T$ (III) $-\left(\frac{\partial A}{\partial V}\right)_T$ (IV) $-\left(\frac{\partial A}{\partial T}\right)_V$

(a) I and II (b) I and IV (c) I only (d) II only

GATE 2017

41. Consider an ideal gas of volume V at temperature T and pressure P. If the entropy of the gas is S, the partial derivative $\left(\partial P / \partial S\right)_V$ is equal to

(a) $\left(\partial T / \partial P\right)_S$ (b) $\left(\partial T / \partial V\right)_P$ (c) $-\left(\partial T / \partial V\right)_S$ (d) $\left(\partial T / \partial S\right)_P$

42. The standard Gibbs free energy change of the reaction shown below is –2.7 kJ mol^{-1}.

$$Sn(s) + Pb^{2+} = Sn^{2+} + Pb(s)$$

Given that $E^0\left(Pb^{2+} / Pb\right)$ is –0.126 V, the value of $E^0\left(Sn^{2+} / Sn\right)$ in V is ________ (up to two decimal places)

43. The Gibbs free energy of mixing is denoted as $\Delta G_{max.}$ 1.0 mole of He, 3.0 moles of Ne and 2.0 moles of Ar are mixed at the same pressure and temperature. Assuming ideal gas behavior, the value of $\Delta G_{max} / RT$ is ___________ (up to two decimal places)

GATE 2018

44. Two moles of an ideal gas X and two moles of an ideal gas Y, initially at the same temperature and pressure, are mixed under isothermal-isobaric condition. The entropy change on mixing is ______________JK^{-1}.

(Upto one decimal place, Use R = 8.31 JK^{-1} mol^{-1})

45. The molar heat capacity of a substance is represented in the temperature range 298K to 400K by the empirical relation $C_{p,m} = 14 + nTJK^{-1}mol^{-1}$, where b is a constant. The molar enthalpy change when the substance is heated from 300K to 350K is 2 kJ mol^{-1}. The value of b is _____________ J K^{-2} mol^{-1}. (Upto two decimal places)

GATE 2019

46. The entropy change for the melting of 'x' moles of ice (heat of fusion is 80 cal g^{-1}) at 273 K and 1 atm pressure is 28.80 cal K^{-1}. The value of 'x' is _______ (Round off to two decimal places)

(Molecucular weight of water = 18 g/mol)

47. An ideal gas occupies an unknown volume V liters (L) at a pressure of 12 atm. The gas is expanded isothermally against a constant external pressure of 2 atm so that its final volume become 3L. The work involved for this expansion process is _______cal. (Round off to two decimal places)

(Gas constant R = 0.082 L atm mol^{-1} K^{-1} = 2 cal mol^{-1} K^{-1})

48. Consider the following equilibrium

$$SO_2(g) + \frac{1}{2}O_2 \rightleftharpoons SO_3(g)$$

At 298 K, the standard molar Gibbs energies of formation, $\Delta_f G^o$, of SO_2(g) and SO_3(g) are –300 and –371 kJ mol^{-1} espectively. The value of the equilibrium constant, K_P at this temperature is _____× 10^{10}. (Round off to the nearest integer)

(Gas constant R = 8.31 J mol^{-1} K^{-1})

GATE 2020

49. When three moles of helium is mixed with one mole of neon at constant temperature and pressure (25ºC, 1 atm), the entropy of mixing (in JK^{-1}, rounded off to two decimal places) is ________

(Given: $R = 8.314\ JK^{-1}\ mol^{-1}$)

50. ΔG_f^0 and ΔH_f^0 for Fe(g) are 370.7 kJ mol^{-1} and 416.3 kJ mol^{-1} at 298 K, respectively. Assuming ΔH_f^0 is constant in the interval 250 K to 375 K, ΔG_f^0 (rounded off to the nearest integer) for Fe(g) at 375 K is:

(a) 338 kJ mol^{-1} (b) 310 kJ mol^{-1} (c) 325 kJ mol^{-1} (d) 359 kJ mol^{-1}

51. The van der Waals constants a and b for gaseous CO are given as 1.49 L^2 atm mol^{-2} and 0.0399 L mol^{-1}, respectively. The fugacity (in atm, rounded off to two decimal places) of CO at 35ºC and 95 atm is _____

(Given: $R = 0.082$ L atm K^{-1} mol^{-1})

GATE 2021

52. A reversible heat engine absorbs 20 kJ of heat from a source at 500 K and dissipates it to the reservoir at 400 K. The efficiency of the heat engine is______%.

53. 2L of gas at 1 atm pressure is reversibly heated to reach a final volume of 3.5 L. The absolute value of the work done on the gas (rounded off to the nearest integer) is _____ Joules.

54. The change in enthalpy (ΔH) for the reaction

$2P(s) + 3Br_2(I) \rightarrow 2PBr_3(l)$

is –243 kJ. In this reaction, if the amount of phosphorus consumed is 3.1 g, the change in enthalpy (rounded off to two decimal places) is ________ kJ.

[Atomic Wt. of P = 31]

THERMODYNAMICS & THERMOCHEMISTRY

ANSWERS KEY

1. (b) 2. (a) 3. (d) 4. (c) 5. (a) 6. (d) 7. (c)
8. (d) 9. (a) 10. (b) 11. (a) 12. (a) 13. (c) 14. (c)
15. (c) 16. (c) 17. (a) 18. (c) 19. (a) 20. (a) 21. (b)
22. (d) 23. (c) 24. (d) 25. (d) 26. (a) 27. (a) 28. (a)
29. (92.13) 30. (b) 31. (d) 32. (840) 33. (b) 34. (a)
35. (–1.38 to –1.39) 36. (11.3 to 11.5) 37. (-7.61) 38. (d) 39. (1001)
40. (a) 41. (c) 42. (-0.14) 43. (6.07) 44. (23.05 JK^{-1})
45. (b = 0.08 Jk^{-2} mol^{-1}) 46. (5.46)
47. (-121.95 CaL)
48. ($K_p = 283 \times 10^{10}$)
49. (18.69 JK^{-1})
50. (355.1 kJmol^{-1})
51. (f = 88.47 atm)
52. (20)
53. (150)
54. (– 12.15 kJ)

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

3

STATISTICAL THERMO

GATE 2005

1.

Column – I	**Column – II**
P. Many electron wave function	I. Adiabatic demagnetization
Q. Low temperature	II. Slater determinant
R. Mean speed	III. Partition function
S. Molecular ensemble	IV. maxwellian distribution
	V. LCAO – MO
	VI. Photoejection

Codes:
(a) P – IV, Q – I, R – VI, S – III
(b) P – II, Q – I, R – IV, S – III
(c) P – II, Q – V, R – VI, S – IV
(d) P – VI, Q – IV, R – III, S – II

2. The vibrational partition function for a molecule with fundamental frequency v is given by

(a) $\exp\left(-\frac{\hbar\upsilon}{k_BT}\right)$
(b) $\left[1-\exp\left(-\frac{\hbar\upsilon}{k_BT}\right)\right]^{-1}$
(c) $\exp\left(-\frac{\hbar\upsilon}{k_BT}\right)\left[1-\exp-\left(\frac{\hbar\upsilon}{k_BT}\right)\right]^{-1}$
(d) $\exp\left(-\frac{\hbar\upsilon}{2k_BT}\right)\left[1-\exp-\left(\frac{\hbar\upsilon}{k_BT}\right)\right]^{-1}$

3. Given that the mean speed of H_2 is 1.78 km s^{-1}, the mean speed of D_2 will be
(a) 1.26 kms^{-1} (b) 2.52 km s^{-1} (c) 5.04 km s^{-1} (d) 3.17 km s^{-1}

GATE 2006

4. As the temperature tends to infinity, the partition function for a two-level system is
(a) 0 (b) 1 (c) 2 (d) infinity

GATE 2007

5. Assuming H_2 and HD molecules having equal lengths, the ratio of the rotational partition functions of these molecules, at temperature above 100 K is
(a) 3/8 (b) 3/4 (c) 1/2 (d) 2/3

6. N non – interacting molecules are distributed among three non – degenerate energy levels $\varepsilon_0 = 0, \varepsilon_1 = 1.38\times10^{21}$ J and $\varepsilon_2 = 2.76\times10^{-21}$ J, at 100 K. If the average total energy of the system at this temperature is 1.38×10^{-18} J,

the number of molecules in the system is:

(a) 1000 (b) 1503 (c) 2354 (d) 2987

GATE 2008

7. At T = 300 K, the thermal energy (k_BT) in cm^{-1} is approximately

(a) 20000 (b) 8000 (c) 5000 (d) 200

8. The total number of ways in which two nonidentical spin – ½ particles can be oriented relative to a constant magnetic field is:

(a) 1 (b) 2 (c) 3 (d) 4

9. A box of volume V contains one mole of an ideal gas. The probability that all N particles will be found occupying one half of the volume leaving the other half empty is

(a) 1/2 (b) 2/N (c) $(1/2)^N$ (d) $(1/2)^{6N}$

10. A certain molecule can be treated as having only a doubly degenerate state lying at 360 cm^{-1} above the nondegenerate ground state. The approximate temperature (K) at which 15% of the molecule will be in the upper state is

(a) 500 (b) 150 (c) 200 (d) 300

GATE 2012

11. The molecular partition function of a system is given by $q(T)=\left(\frac{k_BT}{hc}\right)^{\frac{3}{2}}\left(\frac{8\pi^3 m k_BT}{h^2}\right)^{\frac{3}{2}}$, where the symbols have their usual meanings.

The heat capacity at constant volume for this system is

(a) 3R (b) 6R (c) 9R / 2 (d) 3R / 2

GATE 2014

12. The ratio of molecules distributed between two states is 9.22×10^6 at 300K. the difference in energy (in kJ mol^{-1}) of the two states is _________

GATE 2015

13. For an ideal gas with molar mass M, the molar translational entropy at a given temperature is proportional to

(a) $M^{3/2}$ (b) $M^{1/2}$ (c) e^M (d) ln(M)

14. The rotational partition function of a diatomic molecule with energy levels corresponding to J = 0, 1, is (where, ε is a constant)

(a) $1+e^{-2\varepsilon}$ (b) $1+3e^{-2\varepsilon}$ (c) $1+e^{-3\varepsilon}$ (d) $1+3e^{-3\varepsilon}$

GATE 2016

15. Consider a two-state system at thermal equilibrium with equal degeneracy where the excited state is higher in energy than the ground state by 0.1 eV. The ratio of the population of the excited state to that of the ground state, at a temperature for which k_BT = 0.05 eV, is __________

GATE 2017

16. Consider N particles at temperature T, pressure P, Volume V and chemical potential μ having energy E. The parameters that are kept constant for a canonical ensemble are

(a) N, V, T (b) N, V, E (c) N, P, T (d) μ, V, T

GATE 2019

17. Consider a two-state system at thermal equilibrium having energies 0 and $2k_BT$ for which the degenracies are 1 and 2, respectively. The value of the partition function at the same absolute temperature T is _________. (Round off to two decimal places)

(k_B is the Boltzmann constant)

18. Consider a system of three identical and distinguishable non-interacting particles and three available nondegenerate single particle energy levels having energies 0, ε and 2ε. The system is in contact with a heat bath of temperature T K. A total energy of 2ε is shared by these three particles. The number of ways the particles can be distributed is ______

STATISTICAL THERMO

ANSWERS KEY

1.	(b)	2.	(d)	3.	(a)	4.	(c)	5.	(a)	6.	(a)	7.	(d)
8.	(d)	9.	(c)	10.	(c)	11.	(a)	12.	(39.98)	13.	(b)	14.	(b)
15.	(0.14)	16.	(a)	17.	(1.27)	18.	(6)						

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

4

EQUILIBRIA

GATE 2005

1. The triple point for water is
(a) unique
(b) depends on p but is independent of T
(c) depends on T but is independent of P
(d) depends on both P and T

2. Change in chemical potential (in kJ/mol) for the equilibrium H_2O (liquid) = H_2O (gas) at 298 K is
(a) 8.6
(b) –3.8
(c) 7.87
(d) 3.72

GATE 2006

3. The phases at 55 mole percent B and 108 K are,
(a) solid AB and a solid B phase
(b) solid AB and a liquid phase
(c) solid B and a liquid phase
(d) solid A and a liquid phase

4. What happens if a small amount of solid B is added to the above mixture while keeping the temperature constant?
(a) added B forms compound AB
(b) added B precipitates out
(c) overall liquid phase percentae increases with respect to the overall solid phase
(d) complete solidification takes place

5. The mixture at 25 mole percent B and at 124 K is cooled slowly to 114 K. The resulting phases are
(a) solid AB and solid A
(b) solid AB and liquid
(c) solid AB and solid B
(d) liquid and solid A

GATE 2007

6. 40 millimoles of NaOH are added to 100 mL of a 1.2 M HA and Y M NaA buffer resulting in a solution of pH 5.30. Assuming that the volume of the buffer remains unchanged, the pH of the buffer $\left(K_{HA} = 1.00 \times 10^{-5}\right)$ is
(a) 5.30
(b) 5.00
(c) 0.30
(d) 10.30

7. The number of degrees of freedom for a system consisting of NaCl(s), Na^+(aq) and Cl^- (aq) at equilibrium is
(a) 2
(b) 3
(c) 4
(d) 5

GATE 2008

8. For a one component system, the maximum number of phases that can coexist at equilibrium is

(a) 3 (b) 2 (c) 1 (d) 4

GATE 2009

9. The number of degrees of freedom of a system consisting of solid sucrose in equilibrium with an aqueous solution of sucrose is

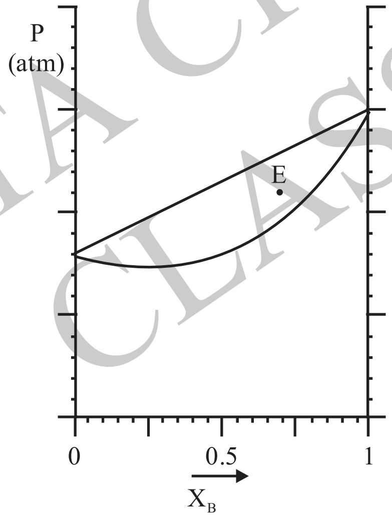
(a) 0 (b) 1 (c) 2 (d) 3

10. Among the following, the equilibrium which is NOT affected by an increase in pressure is

(a) $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$ (b) $H_2(g) + I_2(s) \rightleftharpoons 2HI(g)$

(c) $C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$ (d) $3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$

11. Two liquids B and C form an ideal solution. In the figure below, the vapour pressure P of this solution is shown as a function of the mole fraction X_B, of component B.



Given a state of this vapour-liquid mixture whose overall composition corresponds to point E in the figure, the mole fractino of B in the vapour phase is approximately.

(a) 0.25 (b) 0.53 (c) 0.65 (d) 0.80

GATE 2010

12. Sulfur can exist in four phases. The possible number of triple points is

(a) 1 (b) 2 (c) 3 (d) 4

13. For the pair of reactions given below

(i) $N_2(g)+3H_2(g) \rightleftharpoons 2NH_3(g)$

(ii) $\frac{1}{2}N_2(g)+\frac{3}{2}H_2(g) \rightleftharpoons NH_3(g)$

If at a particular temperature, K_{P1} and K_{P2} are the equilibrium constants for reactions (i) are (ii) respectively, then

(a) $K_{P1} = 2K_{P2}$ (b) $K_{P1} = 2K_{P2}^2$ (c) $K_{P1} = K_{P2}^2$ (d) $K_{P1}^2 = K_{P2}$

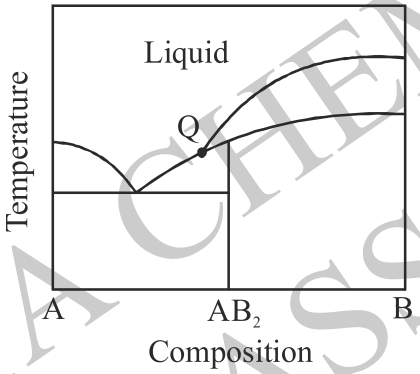
GATE 2011

14. On On the pressure-temperature diagram for a one-component system, the point where the solid-liquid and the liquid-gas curves intersect is:

(a) triple point (b) critical point (c) melting point (d) boiling point

GATE 2012

15. Consider the phase diagram given below.



At the intersection point Q the phases that are in equilibrium are

(a) Solid A, solid B and solid AB_2 (b) Solid A, solid AB_2 and liquid

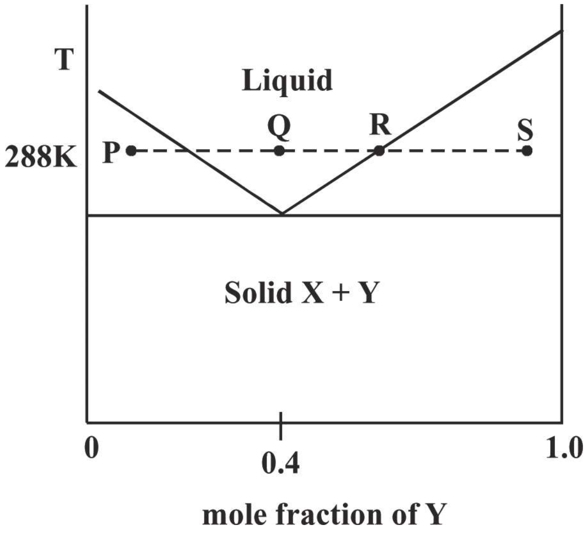
(c) Solid B, solid AB_2 and liquid (d) Solid A, solid B, solid AB_2 and liquid

GATE 2014

16. The enthalpy of fusion of ice at 273K is 6.01 kJ mol^{-1} and the enthalpy of vaporization of water at 273K is 44.83 kJ mol^{-1}. The enthalpy of sublimation (in kJ mol^{-1}) of ice at 273K, is ________

GATE 2016

17. The temperature-composition (T-x) phase diagram of the two-component system made of X and Y is given below. At a temperature of 288K and starting at the point P, Y is added until the composition reaches S. Which of the following statements is NOTR TRUE?



(a) At P, the solid and liquid are present in almost equal proportions
(b) At Q, the system is all liquid
(c) At S, the system has more solid than liquid
(d) At R, the liquid is pure X

GATE 2017

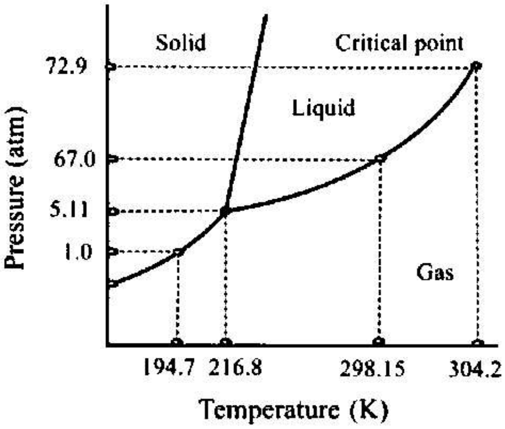
18. m_1 and m_2 are the slopes (dP/dT) of the solid – liquid equilibrium lines in the P – T phase diagrams of H_2O and CO_2, respectively. For P < 10 atm, the values of m_1 and m_2 are
(a) $m_1 > 0$ and $m_2 > 0$ (b) $m_1 > 0$ and $m_2 < 0$ (c) $m_1 < 0$ and $m_2 < 0$ (d) $m_1 < 0$ and $m_2 > 0$

GATE 2018

19. The enthalpy of vaporization of a liquid at its boiling point (T_b = 200 K) is 15.3 kJ mol^{-1}. If the molar volumes of the liquid and the vapour at 200K are 100 and 12000 cm^3 mol^{-1}, respectively, then the slope $\frac{dP}{dT}$ of the liquid-boundary is ___________kPa K^{-1} (Upto two decimal places. Note : 1 Pa = 1 J m^{-1})

GATE 2019

20. Consider the following phase diagram of CO_2 (not to scale). At equilibrium, the INCORRECT statement is:



(a) At 200 K, on increasing the pressure from 1 to 50 atm, CO_2 gas condenses to liquid

(b) It is not possible to obtain liquid CO_2 from gaseous CO_2 below 5.11 atm

(c) Both liquid and gas phase of CO_2 coexist at 298.15 K and 67 atm.

(d) With increasing pressure, the melting point of solid CO_2 increases.

GATE 2021

21. The equilibrium constant for the reaction

(a) $NO(g) \rightleftharpoons N_2O(g) + NO_2(g)$

at 25ºC is closest to:

$[\Delta G^o = -104.18 \text{ kJ}; R = 8.314 \text{ J mol}^{-1} \text{K}^{-1}]$

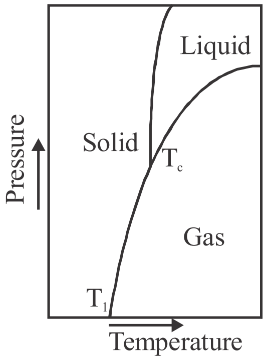
(a) 1.8×10^{18} (b) 1.651 (c) 1.043 (d) 5.7×10^{-19}

22. The reaction

$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$

at 500ºC, with initial pressures of 0.7 bar of CO and 1.0 bar of Cl_2, is allowed to reach equilibrium. The partial pressure of $COCl_2$ (g) at equilibrium is 0.15 bar. The equilibrium constant for this reaction at 500ºC (rounded off to two decimal places) is ______________.

23. The phase diagram of CO_2 is shown below:



The correct statement(s) about CO_2 is/are:

(a) At T_c, it can exist in all three phases.

(b) Below T_c, it does not exist in liquid state.

(c) Above T_c, it does not exist in liquid state.

(d) Above T_1, it does not exist in solid state.

EQUILIBRIA

ANSWERS KEY

1.	(a)	2.	(c)	3.	(b)	4.	(b)	5.	(a)	6.	(b)	7.	(a)
8.	(a)	9.	(c)	10.	(d)	11.	(d)	12.	(d)	13.	(c)	14.	(a)
15.	(c)	16.	(50.84)	17.	(d)	18.	(d)	19.	(6.4339 kP_aK^{-1})			20.	(a)
21.	(a)	22.	(0.32 bar^{-1})	23.	(a,b)								

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

5

KINETICS

GATE 2005

1. A gaseous sample on exposure to total radiant energy of 6.626 J at 300 nm results in the photodissociation of 10^{-3} mol of this sample. Assuming the sample absorbs all the light, the quantum yield for this photochemical reaction is:

(a) 6.023 (b) 0.602 (c) 60.230 (d) 0.060

2. A reaction follows second order rate law, $-\,d[A]/dt = k[A]^2$, if

(a) a plot of [A] versus it is a straight line (b) a plot of 1/[A] versus t is a straight line

(c) a plot of ln [A] versus t is a straight line (d) a plot of $e^{[A]}$ versus t is a straight line

GATE 2006

3. Consider an exothermic reaction $A \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} I$ as the temperature increases

(a) k_1, k_{-1}, and k_1/k_{-1} increases (b) k_1 increases, k_{-1} decreases, and k_1/k_{-1} increases.

(c) k_1, k_{-1} increases and k_1/k_{-1} decreases (d) k_1 and k_{-1} decrease, and k_1/k_{-1} increases.

4. One gram of ^{90}Sr gets converted to 0.953 g after 2 years. The half life of ^{90}Sr, and the amount of ^{90}Sr remaining after 5 years are

(a) 1.44 years and 0.916g (b) 57.6 years and 0.75g

(c) 28.8 years and 0.887g (d) 100 ears and 0.982 g

5. A reaction proceeds through the formation of an intermediate B in an unimolecular reaction

$$A \xrightarrow{k_1} B \xrightarrow{k_b} C$$

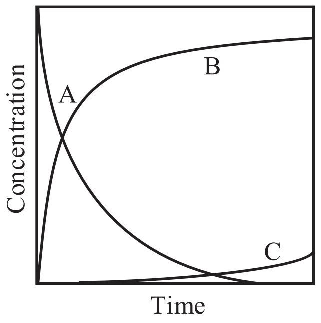
The integrated rate law for this reaction is

(a) $[A] = [A]_0\, e^{-k_a t}$ (b) $[A] = [A]_0 \left(e^{-k_a t} - e^{-k_b t}\right)$

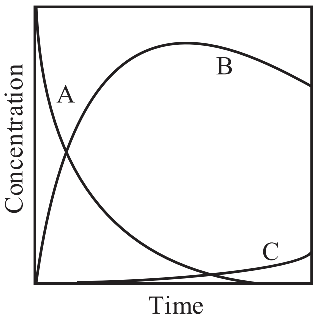
(c) $[A] = \dfrac{[A]_0}{2}\left(1 + \dfrac{k_a e^{-k_b t} - k_b e^{-k_a t}}{k_a - k_b}\right)$ (d) $[A] = [A]_0 \left(1 + e^{-k_a t} - e^{-k_b t}\right)$

6. If $k_a >> k_b$, then concentration vs. time plot for the above reaction is:

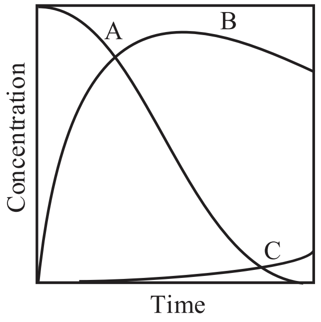
(a)



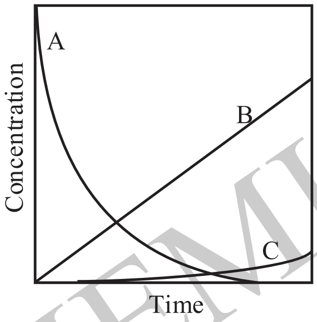
(b)



(c)



(d)



GATE 2007

7. Which of the following statements is NOT correct for a catalyst?
(a) It increases the rate of a reaction
(b) It is not consumed in the course of a reaction
(c) It provides an alternate pathway for the reaction
(d) It increases the activation energy of the reaction

8. The value of the rate constant for the gas phase reaction $2NO_2 + F_2 \rightarrow 2NO_2F$ is 38 $dm^3\ mol^{-1}\ s^{-1}$ at 300 K. The order of the reaction is
(a) 0 (b) 1 (c) 2 (d) 3

9. For the reaction $P + Q + R \rightarrow S$, experimental data for the measured initial rates is given below.

Expt.	Initial conc. P (M)	Initial conc. Q (M)	Initial conc. R (M)	Initial rate (Ms^{-1})
1	0.2	0.5	0.4	8.0×10^{-5}
2	0.4	0.5	0.4	3.2×10^{-4}
3	0.4	2.0	0.4	1.28×10^{-3}
4	0.1	0.25	1.6	4.0×10^{-5}

The order of the reaction with respect to P, Q and R respectively is:
(a) 2, 2, 1 (b) 2, 1, 2 (c) 2, 1, 1 (d) 1, 1, 2

10. Sucrose is converted to a mixture of glucose and fructose in a pseudo first order process under alkaline conditions. The reaction has a half life of 28.4 min. The time required for the reduction of a 8.0 mM sample of sucrose to 1.0 mM is
(a) 56.8 min (b) 170.4 min (c) 85.2 min (d) 227.2 min

11. The reaction, $2NO(g)+O_2(g)\rightarrow 2NO_2(g)$

proceeds via the following steps

$$NO+NO\xrightarrow{k_a}N_2O_2$$
$$N_2O_2\xrightarrow{k_a'}NO+NO$$
$$N_2O_2+O_2\xrightarrow{k_b}NO_2+NO_2$$

The rate of this reaction is equal to

(a) $2k_b[NO][O_2]$ (b) $\left(2k_ak_b[NO]^2[O_2]\right)/\left(k_a+k_b[O_2]\right)$

(c) $2k_b[NO]^2[O_2]$ (d) $k_a[NO]^2[O_2]$

12. The rate constant of two reactions as temperature T are $k_1(T)$ and $k_2(T)$ and the corresponding activation energies are E_1 and E_2 with $E_2 > E_1$. When temperature is raised from T_1 and T_2, which one of the following relations is correct?

(a) $\frac{k_1(T_2)}{k_1(T_1)}=\frac{k_2(T_2)}{k_2(T_1)}$ (b) $\frac{k_1(T_2)}{k_1(T_1)}>\frac{k_2(T_2)}{k_2(T_1)}$ (c) $\frac{k_1(T_2)}{k_1(T_1)}\geq\frac{k_2(T_2)}{k_2(T_1)}$ (d) $\frac{k_1(T_2)}{k_1(T_1)}<\frac{k_2(T_2)}{k_2(T_1)}$

GATE 2008

13. For the reaction $2X_3 = 3X_2$, the rate of formation of X_2 is:

(a) $3\left(-d[X_3]/dt\right)$ (b) $\frac{1}{2}\left(-d[X_3]/dt\right)$ (c) $\frac{1}{3}\left(-d[X_3]/dt\right)$ (d) $\frac{3}{2}\left(-d[X_3]/dt\right)$

14. In a homogeneous catalytic reaction, 1.0 M of a substrate and 1.0 μM of a catalyst yields 1.0 mM of a product in 10 seconds. The turnover frequency (TOF) of the reaction (s^{-1}) is

(a) 10^{-2} (b) 10^{2} (c) 10^{-3} (d) 10^{3}

15. For the reaction given below, the relaxation time is 10^{-6} s. Given that 10% of A remains at equilibrium, the value of $k_1\left(s^{-1}\right)$ is

$$A\underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}}B$$

(a) 9×10^{5} (b) 10^{-5} (c) 10^{5} (d) 9×10^{-5}

16. The mechanism of enzyme (E) catalysed reaction of a substrate (S) to yield product (P) is:

$$E+S\underset{k_2}{\overset{k_1}{\rightleftharpoons}}[ES]\underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}}E+P;\qquad \frac{-d[S]}{dt}=\frac{k_1k_2[S]_0+k_2k_{-2}[P]}{k_1[S]_0+k_{-2}[P]+k_{-1}+k_2}[E]_0$$

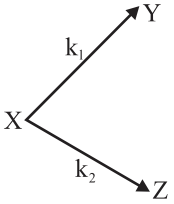
If a small amount of S is converted to P, the maximum rate for the reaction will be observed for

(a) $(k_1+k_2)>>k_1[S]_0$ (b) $(k_{-1}+k_2)<<k_1[S]_0$

(c) $(k_1+k_2)>>k_1[S]_1$ (d) $k_2<<k_1$

GATE 2009

17. For the parallel first order reaction shown below



the value of k1 is $1\times10^{-4}\ s^{-1}$. If the reaction starts from X, the ratio of the concentrations of Y and Z at any given time during the course of the reaction is found to be $\frac{[Y]}{[Z]} = \frac{1}{4}$ The value of k_2 is:

(a) $1\times10^{-4} s^{-1}$ (b) $2.5\times10^{-5} s^{-1}$ (c) $4\times10^{-4} s^{-1}$ (d) $4\times10^{4} s^{-1}$

18. The half-life ($t_{1/2}$) for the hydrolysis of an ester varies with the initial concentration of the reactant ($[E]_0$) as follows:

$[E]_0/10^{-2}$ mol L^{-1}	5.0	4.0	3.0
$T_{1/2}$ /s	240	300	400

The oder of the reaction is:

(a) 0 (b) 1 (c) 2 (d) 3

19. The fluorescene lifetime of a molecule in solution is 10 ns. If the flurosence quantum yield is 0.1, the rate constant of fluroscene decay is:

(a) $1\times10^{9}\ s^{-1}$ (b) $1\times110^{8} s^{-1}$ (c) $1\times10^{7}\ s^{-1}$ (d) $9\times10^{7}\ s^{-1}$

20. The overall rate constant ($k_{overall}$) for the formation of P can be expressed as

(a) k_1k_3/k_2 (b) k_1 (c) $k_1/(k_2+k_3)$ (d) $k_1|(k_2-k_3)$

21. The overall activation energy ($E_{A,overall}$) for the formation of P can expressed as

(a) $\frac{E_{A,1}.E_{A,3}}{E_{A,2}}$ (b) $E_{A,1}$ (c) $E_{A,1}+E_{A,3}-E_{A,2}$ (d) $\frac{E_{A,1}}{E_{A,2}+E_{A,3}}$

GATE 2010

22. The specific rate constant of decomposition of compound is represented by

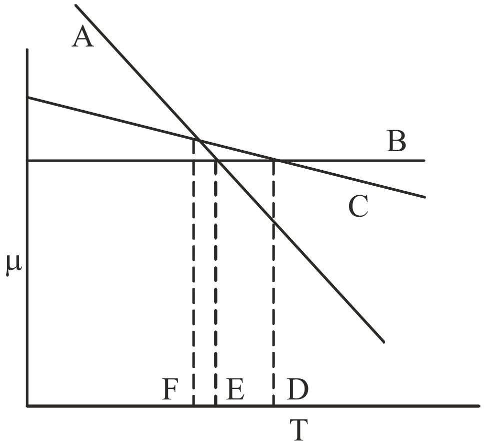
$$Ink = 5.0 - \frac{12000}{T}$$

The activation energy of decomposition for this compound at 300 K is

(a) 24 kcal/mole (b) 12 kcal/mole (c) 24 cal/mole (d) 12 cal/mole

Statement for Linked Answer Q. 54 and Q. 55:

In the m vs T diagram for different phases of the same substance at one atmospheric pressure, the lines A, B and C compound to



23. Based on the above diagram.

(a) A represents the change in chemical potential as a function of temperature for the solid phase, B for the liquid and C for the gas.

(b) A represents the change in chemical potential as a function of temperature for the gas phase, B for the gas and C for the soild.

(c) A represents the change in chemical potential as a function of temperature the liquid phase, B for the gas and C for the solid.

(d) A represent the change in chemical potential as a function of temperature for the gas phase, B for the gas and C for the liquid.

24. From the same diagram

(a) D represents boiling point, E sublimation point and F melting point.

(b) E represents boiling point, D sublimation point and F melting point.

(c) E represents melting point, E sublimation point and F boiling point.

(d) E represents melting point, F sublimation point and E boiling point.

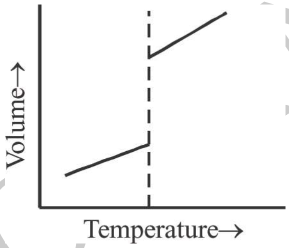
GATE 2011

25. For a given first order reaction, the reactant reduces to 1/4th its initial value in 10 minutes. The rate constant of the reaction is:

(a) 0.1386 min^{-1} (b) 0.0693 min^{-1}

(c) 0.1386 mol L^{-1} min^{-1} (d) 0.0693 mol L^{-1} min^{-1}

26.



According to Ehrenfest classification of phase transitions, the above diagram refers to

(a) Zeroth order phase transition (b) First order phase transition

(c) Second order phase transition (d) λ transition

27. Assuming $k_3[O_3] >> k_2[O_2][M]$, the activation of the overall reaction is

(a) $\frac{E_{a,1}E_{a,3}}{E_{a,2}}$ (b) $E_{a,3} + E_{a,1} - E_{a,2}$ (c) $E_{a,2}$ (d) $E_{a,1}$

28. Under the steady state approximation for the intermediates, the rate of decomposition of ozone, $-\frac{d[O_3]}{dt}$, is

(a) $\dfrac{2k_1k_3[O_3]^2[M]}{k_2[O_2][M]+k_3[O_3]}$ (b) $\dfrac{2k_1k_3[O_3]^2[M]}{k_2[O_2][M]-k_3[O_3]}$

(c) $\dfrac{2k_1k_3[O_3][M]}{k_2[O_2][M]+k_3[O_3]}$ (d) $\dfrac{2k_1k_2[O_3]^2[M]}{k_2[O_2][M]-k_3[O_3]}$

GATE 2012

29. For a reaction involving two steps given below

First step: $G \rightleftharpoons 2H$

Second step: $G + H \rightarrow P$

assume that the first step attains equilibrium rapidly. The rate of formation of P is proportional to

(a) $[G]^{1/2}$ (b) $[G]$ (c) $[G]^2$ (d) $[G]^{3/2}$

30. Consider the reaction, $H_2 + C_2H_4 \rightarrow C_2H_6$

The molecular diamesters of H_2 and C_2H_4 are 1.8Å and 3.6Å respectively. The pre – exponential factor in the rate constant calculated using collision theory in $m^3(\text{mole})^{-1}s^{-1}$ is approximately. (For this reaction at 300 K,)

$\left(\dfrac{8k_BT}{\pi\mu}\right)^{\frac{1}{2}} N_A = 1.11\times10^{27}\, m(\text{mole})^{-1}s^{-1}$, where the symbols have their usual meanings)

(a) 2.5×10^8 (b) 2.5×10^{14} (c) 9.4×10^{17} (d) 9.4×10^{23}

GATE 2013

31. Consider the reaction, $2C(s) + O_2(g) \rightleftharpoons 2CO(g)$ at equilibrium,

The equilibrium can be shifted towards the forward direction by

(a) Increasing the amount of carbon in the system

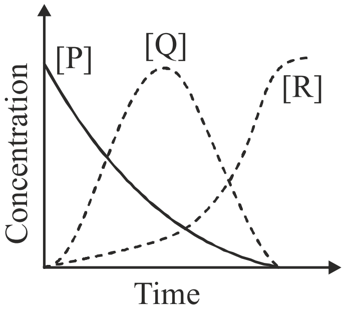
(b) Decreasing the volume of the system

(c) Decreasing the pressure of the system

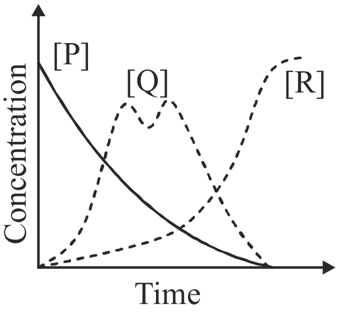
(d) Increasing the temperature of the system

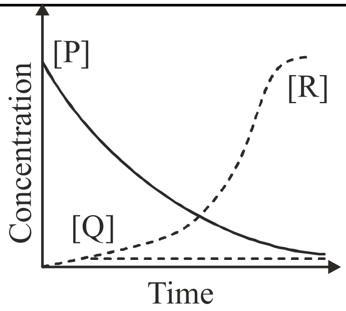
32. For the first order consecutive reaction, $P \rightarrow Q \rightarrow R$, under steady state approximation to [Q], the variation of [P], [Q] and [R] with time are best represented by

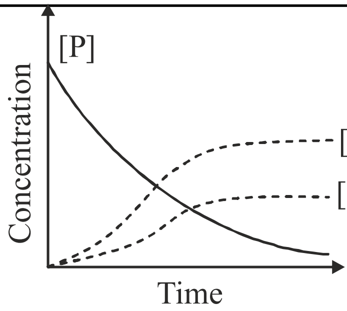
(a)



(b)



(c)


(d)


33. For a reaction of the type $X \underset{k_2}{\overset{k_1}{\rightleftharpoons}} Y$, the correct rate expression is ($[X]_0$ and $[X]$ corresponds to the concentration of X at time t = 0 and t = t, respectively)

(a) $-\frac{d[X]}{dt} = k_1[X]_0 - (k_1 + k_2)[X]$ (b) $-\frac{d[X]}{dt} = (k_1 + k_2)[X] - k_2[X]_0$

(c) $-\frac{d[X]}{dt} = (k_1 + k_2)[X]_0 - k_1[X]$ (d) $-\frac{d[X]}{dt} = (k_1 - k_2)[X] - k_1[X]_0$

34. The temperature dependence of partition are as follows:

$q_{translation} \propto T^{3/2}$ $q_{vibration} \propto T^0$

$q_{rotation} \propto T(\text{linear molecule})$ $q_{rotation} \propto T^{3/2}(\text{non}-\text{linear molecule})$

According to the Conventional Transition State Theory (CTST), the temperature dependence of the Arrhenius pre – exponential factor for a reaction of the type given below is

linear molecule + linear molecule ⇄ non – liner linear transition state → products.

(a) T^{-1} (b) T^0 (c) T^1 (d) T^2

GATE 2015

35. For a gas phase unimolecular reaction at tempeature 298K, with a pre-exponential factor of $2.17 \times 10^{13} s^{-1}$, the entropy of activation ($JK^{-1}\ mol^{-1}$) is ____________

GATE 2016

36. For an elementary bimolecular gas phase reaction, activation energy is 5.5 kJ mol^{-1}. Enthalpy of activation, in kJ mol^{-1}, at 300K is ________. (R = 8.314 $JK^{-1}\ mol^{-1}$)

37. The reaction, $A \rightleftharpoons B$, is first order in both the directions. The forward and reverse rate constants are $4.2 \times 10^{-4} s^{-1}$ and $1.04 \times 10^{-3} s^{-1}$, respectively. The relaxation time for this reaction, in seconds, in a temperature jump experiement is ___________

38. For the following reaction,

$$A + B \underset{k_{-1}=10^4 s^{-1}}{\overset{k_1=10^5 L\,mol^{-1}s^{-1}}{\rightleftharpoons}} I \xrightarrow{k_2=10s^{-1}} P$$

if steady state approximation can be applied on [I], the observed rate constant of product formation, in L mol^{-1}

s^{-1}, will be __________

GATE 2017

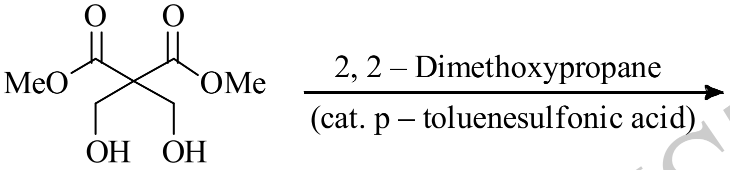
39. The rate constant of a reaction is 1.25×10^{-4} mol L^{-1} s^{-1}. If the initial concentration of the reactant is 0.250 mol L^{-1}, the total time (in second) required for complete conversion is __________

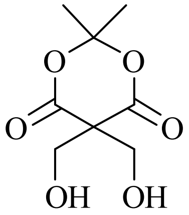
40. The dependence of rate constant k on a temperature T (in K) of a reaction is given by the expression

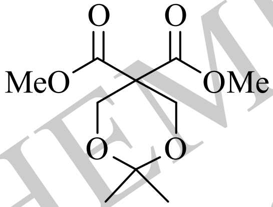
$$\ln k = [(-5000\ K)/T] + 10$$

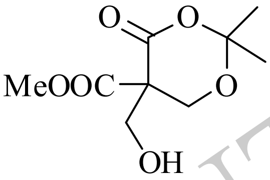
The activation energy of the reaction (in kJ mol^{-1}) is __________ (up to two decimal places)

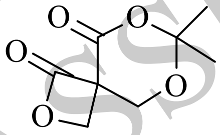
41. The major product obtained in the following reaction is



(a)


(b)


(c)


(d)


42. Under physiological conditions, the conversion of CO_2 to bicarbonate ion by carbonic anhydrase enzyme (MW = 30,000 g mol^{-1}) has a turnover number of 4.00×10^5 s^{-1}. The minimum amount of enzyme (in μg) required to convert 0.44 g of CO_2 to bicarbonate ions in 100 seconds is _________ (up to two decimal places)

GATE 2018

43. According to Eyring state theory for a bimolecular reaction, the activated complex has
   (a) no vibrational degrees of freedom
   (b) vibrational degrees of freedom but they never participate in product formation
   (c) one high frequency vibration that leads to product formation
   (d) one low frequency vibration that leads to prodcut formation

44. The rate constant of a first order reaction, $X \rightarrow Y$, is 1.6×10^{-1} s^{-1} at 300K. Given that the activation energy of the reaction is 28 kJ mol^{-1} and assuming Arrhenium behaviur for the temperature dependence, the total time required to obtain 90% of Y at 350K is ___________s. (Upto to one decimal place, use R = 8.31 JK^{-1} mol^{-1}).

45. Second-order are constant for the reaction between $\left[Co\left(NH_3\right)_5 X\right]^{n+}$ (n = 3 for X = NH_3 and H_2O; n = 2 for

$X = Cl^-$) and $\left[Cr\left(H_2O\right)_6\right]^{2+}$ at room temperature varies with the X as

(a) $NH_3 > H_2O > H_2O$ (b) $Cl^- > H_2O > NH_3$

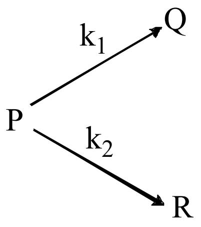
(c) $NH_3 > Cl > H_2O$ (d) $H_2O > NH_3 > Cl^-$

GATE 2019

46. For a biomolecular gas phase reaction $P + Q \rightarrow R$, the pre-exponential factor is 1×10^{13} $dm^3\ mol^{-1}\ s^{-1}$. The standard entropy of activation at 25ºC is ____________ $J\ K^{-1}\ mol^{-1}$. (Round off to two decimal points)

(The standard concentraiton $c^o = 1$ mol dm^{-3}; Planck constant $h = 6.62 \times 10^{-34}$ J s; Boltzmann constant $k_B = 1.38 \times 10^{-23}$ $J\ K^{-1}$; Gas constant $R = 8.31$ $J\ mol^{-1}\ K^{-1}$)

47. Consider the following two parallel irreversible first order reactions at temperature T,



where k_1 and k_2 are the rate constants and their values are 5×10^{-2} and 15×10^{-2} min^{-1} respectively, at temperature T. If the initial concentration of the reactant ‘P’ is 4 mol L^{-1}, then the concentration of product ‘R’ after 10 min of reaction is ________mol L^{-1}. (Round off to two decimal places)

(Assume only P is present at the beginning of the reaction)

GATE 2020

48. For an enzyme catalyzed reaction, the plot of inverse of initial rate against inverse of initial substrate concentration is linear with slope 0.16 s and intercept 2.12 mol^{-1} L s. The estimated value of Michaelis constant (in mol L^{-1}, rounded off to two decimal places) is __________

49. In a reaction, reactant X is converted to products Y and Z consecutively with rate constants 6.0×10^{-2} min^{-1} and 9.0×10^{-3} min^{-1}, respectively. If the initial amount of X is 12.5 moles, the number of moles (rounded off to one decimal place) of Y formed after 10 minutes is ________

50. For the ring opening reaction of cyclopropane to propene at 25ºC, the pre-exponential factor is 4.3×10^{15} s^{-1}. The entropy of activation (in $JK^{-1}\ mol^{-1}$, rounded off to two decimal places) is _______

(Given: $h = 6.626 \times 10^{-34}$ Js; $k_B = 1.38 \times 10^{-23}$ JK^{-1}; $R = 8.314$ $JK^{-1}\ mol^{-1}$)

GATE 2021

51. The rate constants for the decomposition of a molecule in the presence of oxygen are 0.237×10^{-4} L mol^{-1} s^{-1} at 0ºC and 2.64×10^{-4} L mol^{-1} s^{-1} at 25ºC ($R = 8.314$ J mol^{-1} K^{-1}).

The activation energy for this reaction (rounded off to one decimal place) is _______ kJ mol^{-1}.

KINETICS

ANSWERS KEY

1.	(c)	2.	(b)	3.	(c)	4.	(c)	5.	(a)	6.	(b)	7.	(d)
8.	(c)	9.	(c)	10.	(c)	11.	(b)	12.	(d)	13.	(d)	14.	(b)
15.	(a)	16.	(b)	17.	(c)	18.	(c)	19.	(c)	20.	(a)	21.	(c)
22.	(c)	23.	(d)	24.	(d)	25.	(a)	26.	(b)	27.	(d)	28.	(a)
29.	(d)	30.	(a)	31.	(c)	32.	(c)	33.	(b)	34.	(a)	35.	(c)
36.	(5)	37.	(6.6)	38.	(100)	39.	(2000)	40.	(41.57)	41.	(1.576)		
42.	(7.5)	43.	(c)			44.	(289.6 sec)			45.	(b)		
46.	($\Delta S = -12.67$)			47.	(2.59)	48.	($K_M = 0.075 \text{ mol L}^{-1}$)						
49.	($[Y] = 5.4$ moles)			50.	($\Delta S^{\#} = 54.39$)			51.	(65.2 kJ/mol)				

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

6

SURFACE CHEMISTRY

GATE 2008

1. Physisorbed particles undergo desorption at 27ºC with an activation energy of 16.628 kJ mol^{-1}. Assuming first – order process and a frequency factor of 10^{12} Hz, the average residence time (in seconds) of the particles on the surface is

(a) 8×10^{-10} (b) 8×10^{-11} (c) 2×10^{-9} (d) 1×10^{-12}

GATE 2011

2. According to conventional transition state theory, for elementary bimolecular reactions, the molar entropy of activation $\Delta S^{0\ddagger}$ is:

(a) Positive

(b) Zero

(c) Negative

(d) Positive for endothermic and negative for exothermic reactions.

GATE 2013

3. At 273 K and 10 bar, the langmuir adsorption of a gas on a solid surface gave the fraction of surface coverage as 0.01. The Langmuir adsorption isotherm constant is __________ bar^{-1}.

GATE 2014

4. A monoatomic gas, X, adsorbed on a surface, Langmuir adsorption isotherm. A plot of the fraction of surface coverage, θ against the concentration of the gas [X], for very low concentration of the gas, is described by the equation

(a) $\theta = K[X]$ (b) $1-\theta = \frac{1}{K[X]}$ (b) $\theta = K^{1/2}[X]^{1/2}$ (d) $\theta = \frac{K[X]}{1-K[X]}$

GATE 2015

5. The process given below follows the Langmuir adsorption isotherm

$$A_2(g) \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2A_{ads}$$

If θ denotes the surface converage and P denotes the pressure, the slope of the plot of 1/θ versus $1/\sqrt{P}$

(a) $1/\left(K_{eq}\right)^2$ (b) $1/K_{eq}$ (c) $-1/K_{eq}$ (d) $-1/\left(K_{eq}\right)^{1/2}$

GATE 2016

6. Adsorption of CO on charcoal at 273K follows Langmuir isotherm. A plot of P(kPa)/V(cm^3) versus P (kPa) is linear with a slope of 0.01 y-intercept of 0.5. The equilibrium constant, K (kPa^{-1}), for the adsorption is __________.

GATE 2017

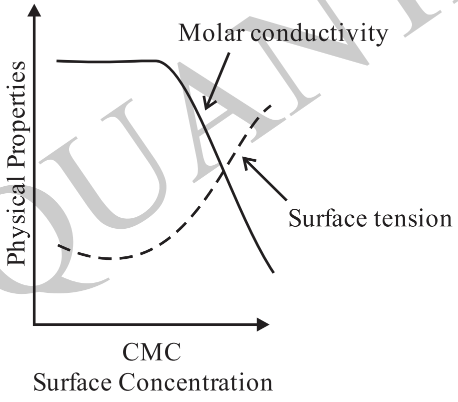
7. The dissociative chemisorptionof X_2(g) one a metal surface follows langmuir adsorption isotherm. The ratio of the rate constants of the adsorption and desorption processes is 4.0 atm^{-1}. The fractional surface coverage of X (adsorbed) at 1.0 atm pressure is ________ (up to two decimal places)

GATE 2018

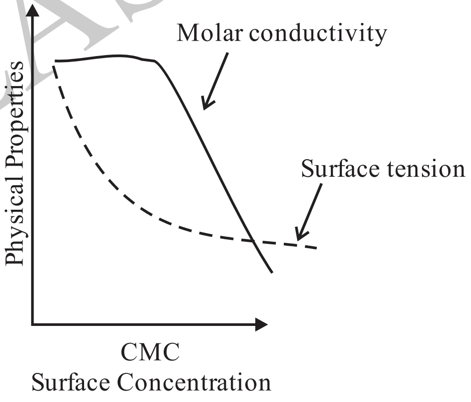
8. For low partial pressure of ozone (O_3), the adsorption of ozone on graphite surface is the fully dissociative in nature and follows Langmuir isotherm. Under these conditions, if the dependence of the surface coverage of graphite (θ) on partial pressure of ozone $\left(P_{O_3}\right)$ is given by $\theta \propto \left(P_{O_3}\right)^x$, the value of x is ____________ (Upto two decimal places)

9. For an ionic micelle-forming surfactant near its critical micelle concentration (CMC), the dependence of molar conductivity and surface tension on surfactant concentration is best represented by

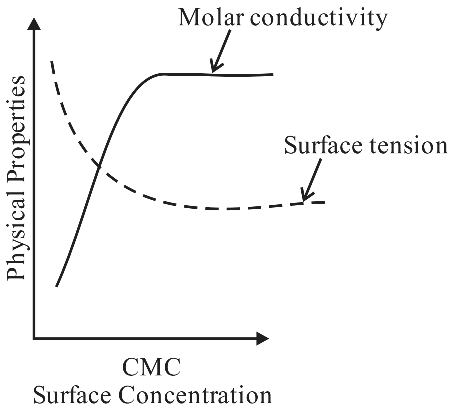
(a)



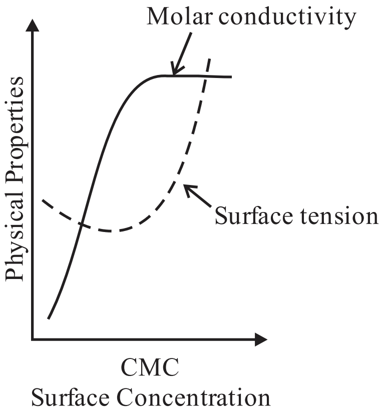
(b)



(c)



(d)



GATE 2019

10. In Freundlich isotherm, a linear relationship is obtained in the plot of (θ = surface coverage and p = partial pressure of the gas)

(a) θ vs p (b) ln (θ) vs ln (p) (c) ln (θ) vs p (d) θ vs ln(p)

11 Micelle formation is accompanied by the

(a) decrease in overall entropy due to ordering

(b) increase in overall entropy mostly due to increase in solvent entropy

(c) increase in overall entropy mostly due to increase in solute entropy

(d) increase in overall entropy and decrease in enthalpy

GATE 2020

12. Adsorption of N_2 on TiO_2 was carried out at 75 K. A plot of $\frac{z}{(1-z)V}$ versus z(z = p/p^0) gives a straight line with an intercept, 4.0×10^{-6} mm^{-3} and slope, 1.0×10^{-3} mm^{-3}. The volume (rounded off to the nearest integer) corresponding to the monolayer coverage is:

(a) 555 mm^3 (b) 690 mm^3 (c) 785 mm^3 (d) 996 mm^3

SURFACE CHEMISTRY

ANSWER KEY

1.	(a)	2.	(c)	3.	(0.001)	4.	(a)	5.	(d)	6.	(100)	7.	(0.67)
8.	(d)	9.	(b)	10.	(b)	11.	(?)	12.	($v_m = 996$ mm^3.)				

7

POLYMER

GATE 2016

1. Amongst the following, the metal that does NOT form homoleptic polynuclear carbonyl is

(a) Mn (b) Fe (c) Cr (d) Co

POLYMER

ANSWER KEY

1. (a)

14. $M_1 = 13.7$

$M_2 = 15.5$

$$\overline{M}_n = \frac{N_1M_1 + N_2M_2 + N_3M_3}{N_1 + N_2 + N_3} = \frac{M_1 + M_2 + M_3}{3}$$

$M_3 = 17.2$

$N_1 = N_2 = N_2 = N$

$$\overline{M}_w = \frac{N_1M_1^2 + N_2M_2^2 + N_3M_3^2}{N_1N_1 + N_2M_2 + N_3M_3} = \frac{M_1^2 + M_2^2 + M_3^2}{(M_1 + M_2 + M_3)}$$

$$\text{P.D.I.} = \frac{\overline{M}_w}{M_n}$$

Correct option is (a)

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

8

ELECTROCHEMISTRY AND CONDUCTANCE

GATE 2005

1. In the reversible chamical reaction taking place under standard condition at 298 K and 1 atm in a Daniel cell, $\mathrm{Zn}\left|\mathrm{Zn}^{2+}(\mathrm{aq})\right|\left|\mathrm{Cu}^{2+}(\mathrm{aq})\right|\mathrm{Cu}$ the heat change is
(a) equal to ΔH^o (b) equal to $T\Delta S^o$ (c) equal to zero (d) equal to ΔU^o

2. If standard emf of the cell, $\mathrm{Cu}\left|\mathrm{Cu}^{2+}(\mathrm{aq})\right|\left|\left[\mathrm{Cu}(\mathrm{NH}_3)_4\right]^{2+}, \mathrm{aq.NH}_3\right|\mathrm{Cu}$ is 0.35, then stability constant of the formation cupric amine complex is
(a) 1.0×10^{27} (b) 8.4×10^{5} (c) 7.0×10^{11} (d) 4.3×10^{13}

3. Aqueous solution of sodium chloride $(\chi_{\mathrm{NaCl}} = 0.015)$ at 298 K is in equilibrium with a water vapour pressure (in torr) of
(a) 23.64q (b) 748.60 (c) 24.36 (d) negligible

4. Average value of enthalpy of vaporisation (in kJ / mol) of water between 363 and 373 K is
(a) 42.50 (b) 40.80 (c) –40.65 (d) –40.80

GATE 2006

5. Given the standard potential for the following half-cell reaction at 298K

$$\mathrm{Cu}^+(\mathrm{aq}) + e^- \rightarrow \mathrm{Cu}(s) \qquad E_0 = 0.52\mathrm{V}$$

$$\mathrm{Cu}^{2+}(\mathrm{aq}) + e^- \rightarrow \mathrm{Cu}^+(\mathrm{aq}) \qquad E_0 = 0.16\mathrm{V}$$

Calculate the ΔG^0 (kJ) for the reaction, $2\mathrm{Cu}^+(\mathrm{aq}) \rightarrow \mathrm{Cu}^+(s) + \mathrm{Cu}^{2+}$

(a) –34.740 (b) –65.720 (c) –69.480 (d) –131.40

GATE 2007

6. For a redox reaction, $Cd^{2+} + 2e^- \rightleftharpoons Cd$, the $(E_p)_{anodic}$ observed in cyclic voltametry at hanging mercury drop electrode is –650 mV vs. SCE. The expected value for $(E_p)_{cathodic}$ is

(a) –708 mV (b) –679 mV (c) –650 mV (d) –621 mV

7. Given that $E_0(Fe^{3+}, Fe) = -0.04\ V$ and $E_0(Fe^{2+}, Fe) = -0.44\ V$, the value of $E_0(Fe^{3+}, Fe^{2+})$ is:

(a) 0.76 V (b) –0.40 V (c) –0.76 V (d) 0.40 V

8. In the mixture obtained by mixing 25.0 mL 1.2×10^{-3} M $MnCl_2$ and 35.0 mL of 6.0×10^{-4} M KCl solution, the concentrations (M) of Mn^{2+}, K^+ and Cl^- ions respectively are

(a) $6.0\times10^{-4}, 3.0\times10^{-4}, 1.5\times10^{-3}$ (b) $6.0\times10^{-4}, 3.0\times10^{-4}, 9.0\times10^{-4}$

(c) $5.0\times10^{-4}, 3.5\times10^{-4}, 1.35\times10^{-3}$ (d) $5.0\times10^{-4}, 3.5\times10^{-4}, 8.5\times10^{-4}$

9. The activity (M) of Mn^{2+} ion in the above solution is

(a) 1.0×10^{-4} (b) 2.0×10^{-4} (c) 3.0×10^{-4} (d) 4.0×10^{-4}

GATE 2008

10. According to the Debye – Huckel limiting law, the mean activity coefficient of 5×10^{-4} mol kg^{-1} aqueous solution of $CaCl_2$ at 25ºC is (the Debye – Huckel constant 'A' can be takento be 0.509)

(a) 0.63 (b) 0.72 (c) 0.80 (d) 0.91

GATE 2009

11. According to the Debye-Hückel limiting law, if the concentration of a dilute aqueous solution of KCl is increased 4-fold, the value of in $\gamma\pm$ ($\gamma\pm$ is the molal mean ionic activity coefficient) will

(a) decease by a factor of 2 (b) increase by a factor of 2

(c) decease by a factor of 4 (d) increase by a factor of 4.

GATE 2010

12. The standard reduction potentials at 298 K for single electrodes are given below:

Electrode	**Electrode Potential (volt)**
Mg^{2+}/Mg	– 2.34
Zn^{+2}/Zn	– 0.76
Zn^{+2}/Fe	– 0.44

From this we can infer that

(a) Zn can reduce both Mg^{2+} and Fe^{2+} (b) Fe can reduce both Mg^{2+} and Zn^{2+}

(c) Mg can reduce both Zn^{2+} and Fe^{2+} (d) Mg can reduce Zn^{2+} but not Fe^{2+}

GATE 2011

13. For a 1 molal aqueous NaCl solution, the mean ionic activity coefficient $(\gamma_\pm)$ and the Deby-Huckel Limiting Law constant (A) are related as

(a) $\log\gamma_\pm = \sqrt{2}\,A$ (b) $\log\gamma_\pm = -\sqrt{2}\,A$ (c) $\gamma_\pm = 10^{A}$ (d) $\gamma_\pm = 10^{-A}$

14. For the concentration cell

$$M \mid M^+\left(aq,\ 0.01\ mol\ dm^{-3}\right) \parallel M^+\left(aq,\ 0.1\ mol\ dm^{-3}\right) \mid M$$

the EMF (E) of the cell at a temperature (T) equals

(a) $2.303\dfrac{RT}{F}$ (b) $-2.303\dfrac{RT}{F}$ (c) $E^0_{m^+/M} + 2.303\dfrac{RT}{F}$ (d) $E^0_{m^+/M} - 2.303\dfrac{RT}{F}$

GATE 2012

15. At 298K, the EMF of the cell

$$pt\left|H_2(lbar)\right|H^+(solution) \parallel Cl^- \mid Hg_2Cl_2Hg$$

is 0.7530V. The standard potential of the calomel electrode is 0.2802V. If the liquid junction potential is zero, the pH of the solution is:

(a) 4.7 (b) 7.4 (c) 8.0 (d) 12.7

16. For the following reaction

$$2MnO_4^- + 5H_2C_2O_4 + 6H^+ \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

$$E^0\left(MnO_4^- / Mn^{2+}\right) = +1.51V \text{ and } E^0\left(CO_2 / H_2C_2O_4\right) = -0.49\ V.$$

At 298 K, the equilibrium constant is:

(a) 10^{500} (b) 10^{338} (c) 10^{38} (d) 10^{833}

GATE 2013

17. A sparingly soluble electrolyte M_2X ionizes as $M_2X \rightleftharpoons 2M^+ + X^{2-}$.

The solubility product (K_{sp}), molal solubility (S) and molal activity coefficient $(\gamma_\pm)$ are related by

(a) $K_{SP} = S^2\gamma_\pm^2$ (b) $K_{SP} = S^3\gamma_\pm^3$ (c) $K_{SP} = 4S^3\gamma_\pm^2$ (d) $K_{SP} = 4S^3\gamma_\pm^3$

18. For the determination of solubility product (K_{SP}) of Fe $(OH)_3$, the appropriate cell representation and its emfare, respectively.

(a) $\left\langle Fe\left|Fe(OH)_3(s)\right|OH^-(aq)Fe^{3+}(aq) \mid Fe\right\rangle$, $-0.750V$

(b) $\left\langle Fe\left|Fe^{3+}(aq)OH^-(aq)\right|Fe(OH)_3(s) \mid Fe\right\rangle$, $-0.750V$

(c) $\left\langle Fe\left|Fe(OH)_3(s)\right|OH^-(aq)Fe^{3+}(aq) \mid Fe\right\rangle$, $+0.750V$

(d) $\left\langle Fe\middle|Fe^{3+}(aq)OH^{-}(aq)\middle|Fe(OH)_3(s)|Fe\right\rangle$, $-0.822V$

19. The value of $\log_e(K_{SP})$ for $Fe(OH)_3$ at 298 K is
(a) –38.2 (b) + 87.6 (c) – 96.0 (d) –87.6

GATE 2014

20. A platinum electrode is immersed in a solution containing 0.1 M Fe^{2+} and 0.1 M Fe^{3+}. Its potential is found to be 0.77V against SHE. Under standard conditions and considering activity coefficients to be equal to unity, the potential of the electrode, when the concentration of Fe^{3+} is increased to 1 M, is ________

GATE 2015

21. Given the E0 values for the following reaction sequence,

$$Mn^{6+} \xrightarrow{1.28V} Mn^{5+} \xrightarrow{2.9V} Mn^{4+} \xrightarrow{0.96} Mn^{3+} \xrightarrow{1.5V} Mn^{2+}$$

the computed value of E^0 for $Mn^{6+} \rightarrow Mn^{2+}$ (in volts) is _____________.

22. The expression for the equilibirum constant (K_{eq}) for the enzyme catalyzed reaction given below, is

$$E + S \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \underset{k_4}{\overset{k_3}{\rightleftharpoons}} P + E$$

(a) $\frac{k_1k_3}{k_2k_4}$ (b) $\frac{k_1k_2}{k_3k_4}$ (c) $\frac{k_2k_3}{k_1k_4}$ (d) $\frac{k_1k_4}{k_2k_3}$

23. The solubility product of AgBr(s) is 5×10^{-13} at 298K. If the standard reduction potential of the half-cell, $E^0_{Ag|AgBr(s)Br^-}$ is 0.07V, the standard reduction potential $E^0_{Ag^+|Ag}$ (in volts) is _________.

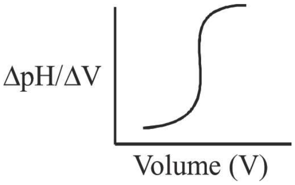
24. The mean ionic activity coefficient of 0.001 molal $ZnSO_4$ (aq) at 298K according to the Debye-Huckel limiting law is (Debye-Huckel constant is 0.509 molal$^{-½}$ _________.

25. The limiting currect (in μA) from the reduction of 3×10^{-4} M Pb^{2+}, using a dropping mercury electrode (DMF) with characteristics, m = 3.0 mg s^{-1} and t = 3s, is (diffusion coefficient of $Pb^{2+} = 1.2\times10^{-5}$ cm^2 s^{-1})_________.

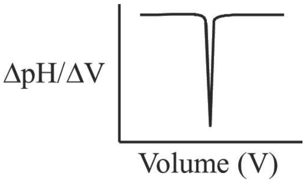
GATE 2016

26. The titration of a strong acid with a strong base is represented by the plot

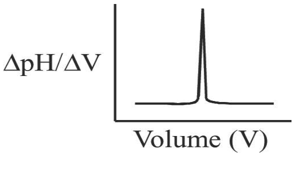
(a)



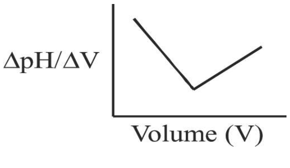
(b)



(c)



(d)



GATE 2017

27. The mobility of a univalent ion in aqueous solution is $6.00 \times 10^{-8}\ m^2\ s^{-1}\ V^{-1}$ at 300 K. Its diffusion coefficient at 300 K is $X \times 10^{-9}\ m^2\ s^{-1}$. The value of X is ________ (up to two decimal places)

28. The ionic activity coefficients of Ca^{2+} and F^- are 0.72 and 0.28, respectively. The mean activity coefficient of CaF_2 is __________ (up to two decimal places)

29. The diffusion limiting current (I_d) at a dropping mercury electrode for an aqueous Mg(II) solution of concentration 'c' (mol L^{-1}) is 300 μA. If 'c' is increased by 0.1 mol L^{-1}, I_d increases to 900 μA. The value of 'c' (in mol L^{-1}) is ___________ (up to two decimal places)

GATE 2018

30. The temperature derivative of electrochemical potential E at constant pressure, $\left(\frac{\partial E}{\partial T}\right)_P$ is given by

(a) $-\frac{\Delta S}{nF}$ (b) $\frac{\Delta S}{nF}$ (c) $\frac{\Delta S}{nFT}$ (d) $-\frac{\Delta S}{nFT}$

31. The Latimer diagrma of oxygen is given below. The value of x is ___________ V. (Upto two decimal places)

$$\begin{tikzcd} O_2 \arrow[r, "+0.70V"] \arrow[rr, bend right] & H_2O_2 \arrow[r, "+0.70V"] & H_2O \end{tikzcd}$$

32. The molar conductivity of a 0.01 M weak acid (HX) at 298K, measured in a conductivity cell with cell constant of $0.4 cm^{-1}$, is $64.4\ Scm^2\ mol^{-1}$. The limiting molar conductivities at infinite dilution of H^+ and X^- at 298K are 350 and 410 S $cm^2\ mol^{-1}$. Ignoring activity coefficients, the pK_a of HX at 298K is ___________ (Upto two decimal places)

GATE 2019

33. Consider the electrochemical cell

$$M(s)|MI_2(s)|MI_2(aq)|M(s)$$

where 'M' is a metal. At 298 K, the standard reduction potential are

$E^o_{M^{2+}(aq)/M(s)} = -0.12V$, $E^o_{MI_2(s)/M(s)} = -0.36V$ and the temperature coefficient is

$\left(\frac{\partial E^o_{cell}}{\partial T}\right)_P = 1.5 \times 10^{-4}\ V\ K^{-1}$. At this temperature the standard enthalpy change for the overall cell reaction,

$\Delta_r H^o$, is ________ kJ mol^{-1}. (Round off to two decimal place)
(Faraday constant F = 96500 C mol^{-1})

GATE 2020

34. The activity of 'm' molal $CuSO_4$ solution can be expressed in terms of its mean activity coefficient $(\gamma_\pm)$ as:

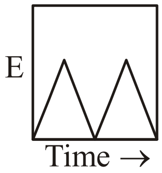
(a) $108m^5\gamma_\pm^5$ (b) $m^2\gamma_\pm^2$ (c) $16m^4\gamma_\pm^4$ (d) $4m^3\gamma_\pm^3$

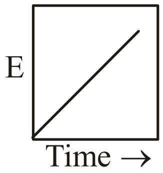
35. At 25ºC, the emf (in volts, rounded off to three decimal places) of the cell,

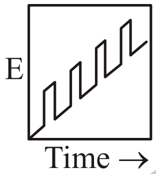
$Ag|AgBr(s)|Br^-(a = 0.20), Cu^{2+}(a = 0.48), Cu^+(a = 0.24)|Pt$ is __________

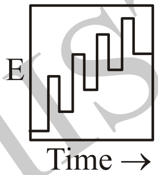
(Given: The standard emf of the cell is 0.082 V; $R = 8.314\ JK^{-1}\ mol^{-1}$; $F = 96500\ C\ mol^{-1}$)

36. The CORRECT 'voltage (E) versus time' excitation signal used in cyclic voltammetry is

(a)


(b)


(c)


(d)


GATE 2021

37. In an electrochemical cell, Ag^+ ions in $AgNO_3$ are reduced to Ag metal at the cathode and Cu is oxidized to Cu^{2+} at the anode. A current of 0.7 A is passed through the cell for 10 min. The mass (in grams) of silver deposited and copper dissolved, respectively, are:

[Faraday Constant = 96, 485 C mol^{-1}, Atomic Weight of Ag = 107.9, Atomic Weight of Cu = 63.55]

(a) 0.235 and 0.138 (b) 0.469 and 0.069 (c) 0.469 and 0.138 (d) 0.235 and 0.069

38. A 5 V battery delivers a steady current of 1.5 A for a period of 2 h. The total charge tht has passed through the circuit is ________ Coulombs.

ELECTROCHEMISTRY AND CONDUCTANCE

ANSWER KEY

1. (b) 2. (c) 3. (c) 4. (b) 5. (a) 6. (b) 7. (a)
8. (c) 9. (d) 10. (d) 11. (a) 12. (?) 13. (a) 14. (a)
15. (c) 16. (b) 17. (d) 18. (b) 19. (d) 20. (0.8291)
21. (1.66) 22. (a) 23. (0.79 to 8.82) 24. (0.73 to 0.75)
25. (0.00312) 26. (c) 27. (1.55) 28. (0.39) 29. (0.05) 30.
(?) 31. (3) 32. (1.23) 33. (-37.693 kJ mol^{-1})
34. ($= m^2\gamma_{\pm}^2$) 35. ($E_{cell} = 0.058$ V) 36. (?) 37. (c)
38. (10800)

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

9

SOLID STATE

GATE 2005

1. The incorrect statement for solid sodium chloride is that
   (a) both sodium and chloride ions adopt inert gas configuration
   (b) the conduction band is full
   (c) the condduction band is empty
   (d) the valence band is full

GATE 2006

2. The atomic radius (in cm) of an element with a body centered cubic unit cell of volume 75.8 cm^3 mol^{-1}, molecular weight 137.3 and density 3.62 g cm^{-3} is
   (a) 1.5×10^{-8} (b) 1.6×10^{-8} (c) 2.0×10^{-8} (d) 2.2×10^{-8}

3. The arrangement of sulphur in zinc blende and wurtzite structures, respectively, are
   (a) hexagonal close packing and cubic close packing
   (b) cubic close packing and hexagonal close packing
   (c) simple cubic packing in both the structures
   (d) hexagonal close packing in both the structures

GATE 2008

4. The lattice parameters for a monoclinic crystal are:
   (a) $a \neq b \neq c; \alpha = \gamma = 90^o$ (b) $a = b \neq c; \alpha = \beta \neq \gamma$
   (c) $a \neq b \neq c; \alpha \neq \beta \neq \gamma$ (b) $a = b = c; \alpha = \gamma = 90^o$

5. When NiO is heated with a small amount of Li_2O in air at 1200ºC, a non – stoichiometric compound $Li_xNi_{(1x)}O$ is formed. This compound is
   (a) an n – type semiconductor containing only Ni^{1+}
   (b) an n – type semiconductor containing Ni^{1+} and Ni^{2+}
   (c) a p – type semiconductor containing Ni^{2+} and Ni^{3+}
   (d) a p – type semiconductor containing only Ni^{3+}

6. The condition for observing diffraction from the nickel surface is
   (a) $\lambda >> 2d$ (b) $\lambda \leq 2d$ (c) $\lambda \leq ad$ (d) $\lambda \geq ad$

7. The minimum value of $\varphi(V)$ for the electron to diffract from the (100) planes is

(a) 3000 (b) 300 (c) 30 (d) 3

GATE 2009

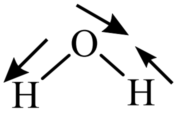
8. The X-ray powder pattern of NaCl shows an intense cone at $\theta = 15.87°$ using X-rays of wave length 1.54×10^{-8} cm. The spacing between the planes (in Å) of NaCl crystal is

(a) 1.41 (b) 2.82 (c) 4.23 (d) 5.63

9. The reducible representation corresponding to the three translational degrees of freedom, Γ_u, is:

(a) 3, 1, 1, 1 (b) 3, –1, 1, 1 (c) 3, –1, –1, –1 (d) 3, 1, –1, –1

10. The asymmertric stretching mode of the H_2O is shown below. The molecular plane is yz and the symmetry axis of H_2O is z.



This vibration transforms as the irreducible representation

(a) A_1 (b) B_1 (c) A_2 (d) B_2

GATE 2010

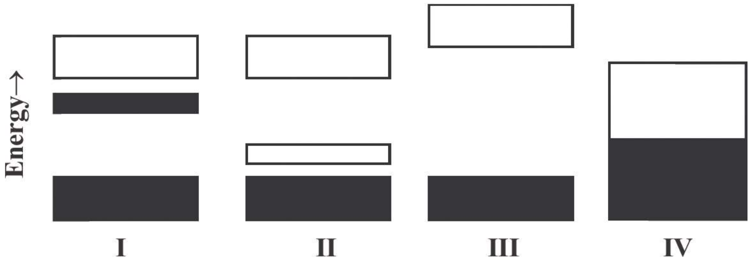
11. Band theory predicts that magnesium is an insulator. However, in practice it acts as a conductor due to

(a) presence of filled 3s orbital (b) overlap of filled 2p and filled 3s orbital

(c) overlap of filled 3s and empty 3p orbital (d) presence of unfilled 3p orbital

GATE 2011

12. The band structure in an n-type semiconductor is



(a) I (b) II (c) III (d) IV

GATE 2012

13. For a face centered cubic lattice, the Miller indices for the first Bragg's peak (smallest Bragg angle) are

(a) 002 (b) 111 (c) 001 (d) 110

GATE 2013

14. A crystal has the lattice parameters $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^o$. The crystal system is

(a) Tetragonal (b) Monoclinic (c) Cubic (d) Orthorhombic

15. A metal crystallizes in the face – centered cubic lattice parameter of 4.20Å. The shortest atom to atom contact distance in the lattice is

(a) 4.20 Å (b) 2.97 Å (c) 2.42 Å (d) 2.10 Å

GATE 2014

16. Molybdenum crystallizes in a bcc structure with unit cell dimensions of 0.314 nm. considering the atomic mass of molybdenum to be 96, its density (in kg m^{-3}) is __________

GATE 2015

17. Which one of the following statements is INCORRECT?

(a) Frenkel defect is a cation vacancy and a cation interstitial

(b) Frenkel defect is an anion vacancy and a cation interstitial

(c) Density of a solid remains unchanged in case of Frenkel defects.

(d) Density of a solid decreses in case of Schottky defects.

18. The distance between two successive (110) planes in a simple cubic lattice with lattice parameter 'a' is

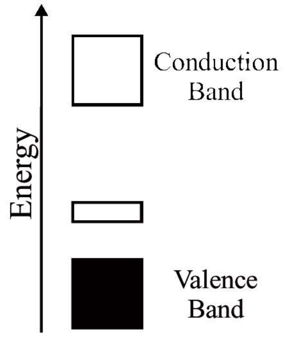
(a) $\sqrt{2}\,a$ (b) $\sqrt{3}\,a$ (c) $2\sqrt{2}\,a$ (d) $\frac{a}{\sqrt{2}}$

GATE 2016

19. When crystals of sodium chloride are heated in the presence of sodium vapor, they turn yellow. This is due to the formation of

(a) Schottky defects (b) Frenkel defects (c) F-centres (d) H-centres

20. The band structure given below represent a



(a) n-type semiconductor formed by doping Si with B

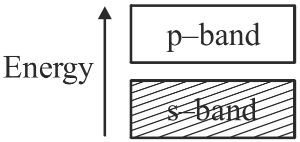
(b) n-type semiconductor formed by doping Si with P

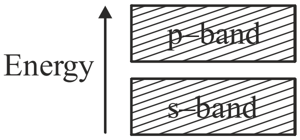
(c) p-type semiconductor formed by doping Si with P

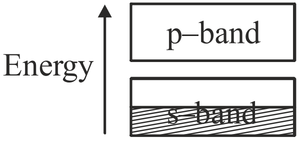
GATE 2017

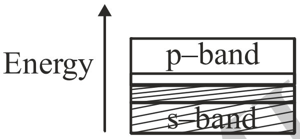
21. The energy band diagram for magnesium is

(The hatched and unhatched regions in the figure correspond to filled and unfilled regions of the band, respectively.)

(a) 

(b) 

(c) 

(d) 

22. P, F and I represent primitive, face – centered and body – centered lattices, respectively. The lattice types of NaCl and CsCl, respectively, are

(a) F and I (b) F and P (c) I and P (d) P and I

GATE 2019

23. The INCORRECT statement about the solid-state structure of CsCl and CaF_2 is:

(a) Cations in both solids exhibit coordination number 8.

(b) CsCl has bcc type structure and CaF_2 has cubic close pack structure

(c) Radius ratio for Cs/Cl and Ca/F is 0.93 and 0.73, respectively

(d) Both exhibit close pack structure

GATE 2020

24. For a cubic crystal system, the powder X-ray diffraction pattern recorded using Cu K_α soucrce ($\lambda = 1.54$ Å) shows a peak at 33.60° (2θ) for (111) plane. The lattice parameter ‘a’ (in Å, rounded off to two decimal place) is _________

25. Consider that AgX crystallizes in rock salt structure. The density of AgX is 6477 kg/m^3 and unit cell length is 577.5 pm. Atomic weight of Ag is 107.87 g mol^{-1}. The atomic weight of X (in g mol^{-1}, rounded off to two decimal places) is ________

SOLID STATE

ANSWERS KEY

1.	(b)	2.	(d)	3.	(b)	4.	(?)	5.	(c)	6.	(?)	7.	(d)
8.	(b)	9.	(d)	10.	(b)	11.	(c)	12.	(a)	13.	(b)	14.	(b)
15.	(b)	16.	(10137)	17.	(b)	18.	(d)	19.	(c)	20.	(d)	21.	(d)
22.	(b)	23.	(b)	24.	(= 4.61 Å)			25.	(78.33g/mol)				

10

GROUP THEORY

GATE 2006

1. A molecule has a 2-fold axis and a mirror plane perpendicular to that. The point group must have a

(a) C_2 axis (b) Centre of inversion (c) σ_h plane (d) σ_v plane

2. The $A_1 \rightarrow A_2$ transition for a molecule having C_{3v} symmetry is

(a) due to dipole pointing in X direction (b) due to dipole pointing in y direction

(c) due to dipole pointing in z direction (d) not allowed

3. The symmetry elements that are present in BF_3 are

(a) $C_3, \sigma_v, \sigma_h, 3C_2$ (b) $C_3, 3C_2, S_2, \sigma_v$ (c) $C_3, 3C_2, \sigma_h, S_2$ (d) $C_3, \sigma_h, \sigma_v, i$

GATE 2007

4. The S_2 operation on a molecule with the axis of rotation as the z axis, moves a nucleus at (x, y, z) to

(a) (–x, –y, x) (b) (x, –y, – z) (c) (– x, y, – z) (d) (– x, – y, – z)

5. The number of distinct symmetry operations that can be performed on the molecule is:

(a) 2 (b) 4 (c) 6 (d) 8

6. The number of irreducible representations of the point group of the molecule is:

(a) 1 (b) 2 (c) 3 (d) 4

7. If two H atoms of the above molecule are also replaced by F atoms, the point group of the resultant molecule will be

(a) C_i (b) C_{2h} (c) C_{2v} (d) D_{2h}

GATE 2008

8. The point group of NSF_3 is:

(a) D_{3d} (b) C_{3h} (c) D_{3h} (d) C_{3v}

9. The Td point group has 24 elements and 5 classes. Given that it has two 3 – dimensional irreducible representation, the number of one dimensional irreducible representation is:

(a) 1 (b) 2 (c) 0 (d) 3

GATE 2010

10. The point group of ClF_3 molecule and its corresponding number of irreducible representation are respectively.

(a) C_{3v} and 4 (b) C_{2v} and 4 (c) C_{3v} and 4 (d) C_{2v} and 3

GATE 2012

11. Symmetry operations of the four C_2 axes perpendicular to the principle axis belong to the same class in the point group (s)

(a) D_4 (b) D_{4d} (c) D_{4h} (d) D_{4h} and D_{4d}

GATE 2013

12. The point group symmetryof $CH_2 = C = CH_2$ is

(a) D_{2h} (b) C_{2h} (c) C_{2v} (d) D_{2d}

13. Conversion of boron trifluoride to tetrafluoroborate accompanies

(a) Increase in symmetry and bond elongation

(b) Increase in symmetry and bond contraction

(c) Decrease in symmetry and bond contraction

(d) Decrease in symmetry and bond elongation

GATE 2014

14. The number of C_2 axes in CCl_4 is __________

GATE 2020

15. The character table for a pyramidal AB_3 molecule of C_{3v} point group is given below:

C_{3v}	E	$2C_3$	$3\sigma_v$		
A_1	1	1	1	z	x^2+y^2, z^2
A_2	1	1	−1	R_z	
E	2	−1	0	$(x, y)(R_x, R_y)$	$(x^2-y^2, xy)(xz, yz)$

The reducible representation of pyramidal AB_3 is

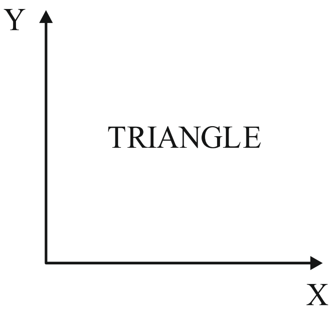
C_{3v}	E	$2C_3$	$3\sigma_v$
Γ	12	0	2

The CORRECT option representing all the normal Raman active modes of pyramidal AB_3 is:

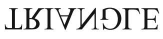
(a) $A_1 + A_2 + 2E$ (b) $2A_1 + 2E$ (c) $3A_1 + A_2 + E$ (d) 3E

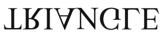
GATE 2021

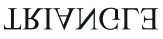
16.

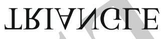


The mirror image of the above text about the x – axis is

(a) 

(b) 

(c) 

(d) 

GROUP THEORY

ANSWER KEY

1.	(b)	2.	(d)	3.	(a)	4.	(d)	5.	(b)	6.	(d)	7.	(d)
8.	(?)	9.	(b)	10.	(b)	11.	(b)	12.	(d)	13.	(a)	14.	(?)
15.	(?)	16.	(?)										

11

PHYSICAL SPACTRA

GATE 2005

1. Resonant frequencies for EPR and NMR are respectively in the spectral region
(a) micro wave and far – IR
(b) far – IR and microwave
(c) radiofrequency and microwave
(d) microwave and radiofrequency

2.

Column – I **(Spectral Technique)**	**Column – II** **(Selection Rule)**
P. Rotational transition	I. $\Delta v = \pm 1$
Q. Vibrational transition	II. $\Delta J = 0$
R. Electronic transition in atoms	III. $\Delta J = \pm 1$
S. Molecular ensemble	IV. $\Delta l = \pm 1$
	V. $\Delta m_l = \pm 1$
	VI. $\Delta v = 0$
	VII. $\Delta l = 0$

Codes:
(a) P – I, Q – VI, R – VII, S – V
(b) P – II, Q – I, R – IV, S – V
(c) P – III, Q – I, R – IV, S – V
(d) P – I, Q – VI, R – VII, S – V

3. Out of the following, the one which is not an excitation source for IR spectrometer is
(a) Tungsten filament lamp
(b) Nernst glower
(c) Deuterium lamp
(d) Mercury arc

GATE 2006

4. The zero-point energy of the vibration of $^{35}Cl_2$ mimicking a harmonic oscillator with a force constant k = 2293.8 Nm^{-1} is
(a) $10.5\times10^{-21}J$
(b) $14.8\times10^{-21}J$
(c) $20\times10^{-21}J$
(d) $29.6\times10^{-21}J$

5. The molecular active in rotational microwave, infrared absorption as well as rotational Raman spectra is:
(a) CO_2
(b) SF_6
(c) HCl
(d) H_2.

GATE 2007

6. The selection rules for the appearance, of P branch in the rotational – vibrational absorption spectra of a diatomic molecule within rigid rotor – harmonic oscillator model are

(a) $\Delta v = \pm$ and $\Delta J = \pm 1$ (b) $\Delta v = +1$ and $\Delta J = +1$

(c) $\Delta v = +1$ and $\Delta J = -1$ (d) $\Delta v = -1$ and $\Delta J = -1$

GATE 2008

7. The rotational constant for CO in the ground and the first excited vibrational states are 1.9 and 1.6 cm^{-1}, respectively. The % change in the internuclear distance due to vibrational excitation is

(a) 9 (b) 30 (c) 16 (d) 0

8. The fundamental transition (cm^{-1}) of the diatomic molecule is at:

(a) 2157 (b) 2170 (c) 2183 (d) 2196

9. The anharmonicity constant (cm^{-1}) of the diatomic molecule is:

(a) 0.018 (b) 0.012 (c) 0.006 (d) 0.003

GATE 2009

10. The fundamental vibrational wavenumbers for H_2 and I_2 are 4403.2 cm^{-1} and 214.5 cm^{-1}, respectively. The relative population of the first excited vibrational states of these two molecules compared to their respective ground states at 300 K are respectively.

(a) 6.75×10^{-1} and 3.57×10^{-1} (b) 6.75×10^{-1} and 3.57 and 3.57×10^{-1}

(c) 3.57×10^{-6} and 6.75×10^{-1} (d) 3.57×10^{-1} and 6.75×10^{-1}

11. The rotational Raman spectrum of $^{19}F_2$ shows a series of Stokes lines at 19230. 769 cm^{-1} , 19227.238cm^{-1} and 19223.707 cm^{-1}. The rotational constant for $^{19}F_2$ in GHz is:

(a) 26.484 (b) 52.968 (c) 105.936 (d) 3.531

GATE 2010

12. The most populated rotational state for HCl(B = 8.5 cm^{-1}) at 300 K is:

(a) 2 (b) 3 (c) 5 (d) 7

13. The ratio of life times of two states that gives rise to line widths of 1.0 cm^{-1} and 0.2 cm^{-1} respectively is:

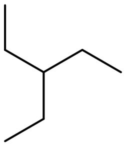
(a) 1 : 2 (b) 1 : 5 (c) 2 : 1 (d) 5 : 1

GATE 2011

14. The region of electromagnetic spectrum employed in the electron spin resonance (ESR) spectroscopy is:

(a) radiowave (b) microwave (c) infrared (d) visible

15. The point group symmetry of the given planar shape is:



(a) D_{3h} (b) C_3 (c) C_{3h} (d) C_{3v}

16. The frequency of radiation (in cm^{-1} units) required to vibrationally excite the molecule from v = 0 to v = 1 state is

(a) 3184.8 (b) 2123.2 (c) 061.6 (d) 840.0

17. The frequency of radiation (in cm^{-1} units) required to rotationally excite the molecule from J = 0 to J = 1 state is

(a) 1.4 (b) 2.8 (c) 3.2 (d) 3.6

GATE 2012

18. The bond that gives the most intense band in the infrared spectrum for its stretching vibrations is

(a) C – H (b) N – H (c) O – H (d) S – H

19. The rotational constant (usually denoted as B) for the oxygen molecule is

(a) 1.2 cm^{-1} (b) 2.0 cm^{-1} (c) 3.0 cm^{-1} (d) 6.0 cm^{-1}

20. The next rotational Stokes line is expected at

(a) 20467 cm^{-1} (b) 20469 cm^{-1} (c) 20471 cm^{-1} (d) 20475 cm^{-1}

GATE 2013

21. the infrared spectrum of HCl gas shows an absorption band centered at 2885 cm^{-1}. The zero point energy of HCl molecule under hamonic oscillator approximation is:

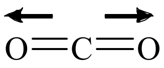
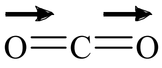
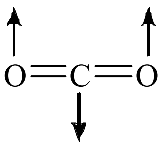
(a) 2.866×10^{-22} J (b) 2.8665×10^{-20} J (c) 5.7330×10^{-22} J (d) 5.7330×10^{-20} J

GATE 2014

22. The number of IR active vibrational normal modes of CO_2 is _________

GATE 2016

23. Of the vibrational modes given below, the IR active mode(s) is(are)

(i) 
(ii) 
(iii) 

(a) (ii) only (b) (ii) only (c) (i) and (ii) (d) (ii) and (iii)

GATE 2018

24. For a diatomic vibrating rotor, in vibrational level v = 3 and rotational level J, the sum of the rotational and vibrational energies is 11493.6 cm^{-1}. Its equilibrium oscillation frequency is 2998.3 cm^{-1}, anharmonicity constant is 0.0124 and rotational constant under rigid rotor approximation is 9.716 cm^{-1}. The value of J is __________. (Up to nearest integer)

25. The spacing between the two adjacent lines of the microwave spectrum of $H^{35}Cl$ the corresponding spacing for $D^{35}Cl$ is ___________ $\times 10^{11}$ Hz. (Upto two decimal places)

GATE 2020

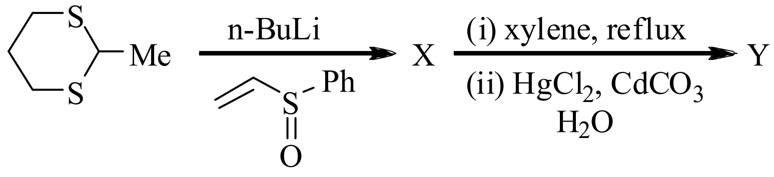
26. The frequency (in cm^{-1}, rounded off to two decimal places) for pure rotational line in the spectrum of NO molecule due to change in the quantum number from J = 1 to J = 2 is ______
(Given: Moment of inertia of NO = 1.6427×10^{-46} kg m^2; h = 6.626×10^{-34} J s; c = 3×10^8 m/s)

27. Assuming no interaction between vibrational and rotational energy levels in HF, the frequency (in cm^{-1}, rounded off to the nearest integer) of the R branch line originating from J = 4 in its IR spectrum is _____
(Given: Rotational constant for HF = 19.35 cm^{-1}; $\bar{\nu}_0 = 4138.52\ cm^{-1}$)

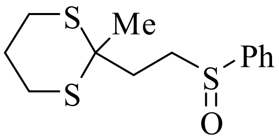
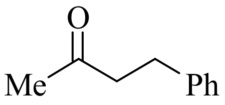
GATE 2021

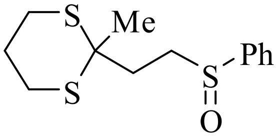
28. The fundamental vibrational frequency of $^1H^{127}I$ is 2309 cm^{-1}. The force constant for this molecule (rounded off to the nearest integer) is ______ N m^{-1}.
[N = 6.022×10^{22}, c = 3.0×10^8 m s^{-1}]

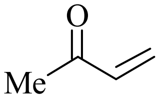
29. In the following reaction

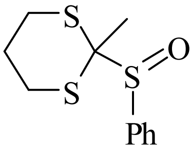


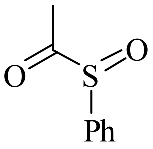
the major products X and Y, respectively, are:

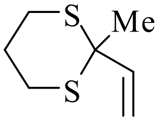
(a)  and 

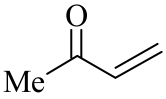
(b) 

and 

(c) 

and 

(d) 

and 

PHYSICAL SPACTRA

ANSWER KEY

1. (c) 2. (c) 3. (d) 4. (b) 5. (c) 6. (c) 7. (8.9 $\simeq$ 9%)

8. (b) 9. (c) 10. (b) 11. (= 26.484 GHz) 12. (b) 13. (b)
14. (b) 15. (c) 16. (c) 17. (b) 18. (?) 19. ($B = 1.2\ cm^{-1}$)
20. (b) 21. (b) 22. (c) 23. (d) 24. (12) 25. ($B_{DCl} = 2.95 \times 10^{11}$ Hz)
26. ($6.81\ cm^{-1}$) 27. (4332.02 cm-1) 28. (311 Nm-1) 29. (b)

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

12

SOLUTION

GATE 2013

1. The moment of iertia of a homonuclear diatomic molecular is 7.5×10^{-45} kg m^2. Its rotational partition function at 500 K is___________

GATE 2014

2. A plot of osmotic pressure against concentration (gL^{-1}) of a polymer is constructed. The slope of the plot

(a) increases with increase in temperature

(b) increases with increase in molar mass of the polymer

(c) decreases with decrease in concentration of the polymer

(d) decreases with increase in temperature.

GATE 2015

3. Which of the following properties are characteristics of an ideal solution?

(i) $(\Delta_{mix}G)_{T,P}$ negative

(ii) $(\Delta_{mix}S)_{T,P}$ is positive

(iii) $(\Delta_{mix}V)_{T,P}$ is positive

(iv) $(\Delta_{mix}H)_{T,P}$ is negative.

(a) (i) and (iv)
(b) (i) and (ii)
(c) (i) and (iii)
(d) (iii) and (iv)

4. A liquid has vapor pressure of $2.02 \times 10^3 N\, m^{-2}$ at 293 K and heat of vaporization of 41 kJ mol^{-1}. The boiling point of the liquid (in Kelvin) is _________.

GATE 2019

5. The normal boiling point of a compound (X) is 350 K (heat of vaporization, $\Delta_{vap}H = 30$ kJ mol^{-1}). The pressure required to boil 'X' at 300 K is ________ Torr. (Round off to two decimal places)

(Ignore the temperature variation of $\Delta_{vap}H$; Gas constant R = 831 J mol^{-1} K^{-1} and 1 atm = 760 Torr)

GATE 2020

6. At 30ºC, the vapor pressure and density of a 1.0 M aqueous solution of sucrose are 31.207 mm Hg and 1.1256 g/mL, respectively. If the vapor pressure of pure water at 30ºC is 31.824 mm Hg, the activity coefficient (rounded off to three decimal places) of water in the given solution is ________

(Given: The molar mass of sucrose = 342.3 g mol^{-1})

GATE 2021

7. The vapour pressure of toluene (Mol. Wt. = 92) is 0.13 atm at 25 ºC. If 6 g of a hydrocarbon is dissolved in 92 g of toluene, the vapor pressure drops to 0.12 atm. The molar mass of the hydrocarbon (rounded off to the nearest integer) is_______.

8. hexane and heptane are completely miscible. At 25ºC, the vapor pressures of hexane and heptane are 0.198 atm and 0.06 atm, respectively. The mole fractions of hexane and heptane in the vapor for a solution containing 4M hexane and 6M heptane, respectively, are:

(a) 0.600 and 0.400 (b) 0.400 and 0.600 (c) 0.688 and 0.312 (d) 0.312 and 0.688

9. A laser Raman spectrometer operating at 532 nm is used to record the vibrational spectrum of Cl_2 having its fundamental vibration at 560 cm^{-1}. The Stokes line corresponding to this vibration will be observed at ________ cm^{-1}. (Rounded off to the nearest integer)

SOLUTION

ANSWER KEY

1. (4691.7) 2. (a) 3. (b) 4. (382 to 385) 5. (136.32 Torr)
6. (1.003) 7. (x = 72 g /mol) 8. (d) 9. (18237 cm^{-1})

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

13

PHOTOCHEMISTRY

GATE 2005

1. A solution containing 47 ppm of a compound X (FW 225) has a transmittance of 29.7% in a 1.5 cm cell at 400 nm. The molar absorptivity in L mol^{-1} cm^{-1} is
(a) 1.89×10^3 (b) 1.42×10^3 (c) 1.68×10^3 (d) 1.79×10^3

GATE 2015

2. The percent transmittance of 8×10^{-5}M solution of $KMnO_4$ is 39. when measured at 510 nm in a cell of path length of 1cm. The absorbance and the molar extinction coefficient (in M^{-1} cm^{-1}) of this solution are, respectively
(a) 0.30 and 4500 (b) 0.35 and 4800 (c) 0.4 and 5000 (d) 0.48 and 5200

GATE 2018

3. The absorption maxima of two dyes X and Y are 520 and 460 nm, respectively. The absorbance data of these measured in a 1cm path length cell are given in the table below.

Dye solution	Absorbance at 460 mm	Absorbance at 52 mm
X (9 mM)	0.144	0.765
Y (12 nM)	0.912	0.168
Mixture of X and Y	0.700	0.680

GATE 2020

4. A solution containing a metal complex absorbs at 480 nm with molar extinction coefficient of 15,000 L mol^{-1} cm^{-1}. If the path length of the cell is 1.0 cm and transmittance is 20.5%, the concentration (in mol L^{-1}) of the metal complex is:
(a) 2.29×10^{-5} (b) 8.75×10^{-5} (c) 4.59×10^{-5} (d) 1.37×10^{-5}

5. Fluorescence quantum yield and fluorescence lifetime of a molecule are 0.4 and 5×10^{-9} s, respectively. If the fluorescence decay rate constant is $Y \times 10^7$ s^{-1}, the value of Y (rounded off to nearest integer) is ________

GATE 2021

6. The number of photons emitted per nanosecond by a deuterium lamp (400 nm) having a power of 1 microwatt (rounded off to the nearest integer) is _______.

   [$h = 6.626 \times 10^{-34}$ kg m^2 s^{-1}; $c = 3.0 \times 10^8$ m s^{-1}]

7. The molar absorption coefficient of a substance dissolved in cyclohexane is 1710 L mol^{-1} cm^{-1} at 500 nm. The reduction in intensity of light of the same wavelength that passes through a cell of 1 mm path length containing a 2 mmol L^{-1} solution (rounded off to one decimal place) is _________%.

PHOTOCHEMISTRY

ANSWERS KEY

1. (c) 2. (c) 3. (7.7967 mM) 4. (4.59×10^{-5} mol/L) 5. (y = 8)

6. (2012) 7. (544%)

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

14

GASES

GATE 2006

1. As per the kinetic theory of ideal gases, which of the following statements is NOT correct?

   (a) gas particles have mass but no volume

   (b) partciles are in a Brownian motion between collisions.

   (c) during the ocllision, the system does not lose energy

   (d) particles exert same force per unit area on all sides of the container.

2. Which of the following statements in NOT correct regarding fugacity of a Van der Wawals gas?

   (a) fugacity increases with increase in b

   (b) fugacity decreases wit increase in a

   (c) fugacity is equal to zero if compressibility is zero

   (d) fugacity is equal to one if compressibility is one

3. One mole each of H_2CO_3, and Na_2CO_3 are added to water to prepare one litre solution. The pH of the solution is.

   (a) 6.37 (b) 8.31 (c) 10.25 (d) 7

4. One mole each of acetic acid and sodium acetate are dissolved in 1kg of water. Boiling point of the resulting solution is

   (a) 100.51 °C (b) 101.02 °C (c) 101.53 °C (d) 102.04 °C

GATE 2008

5. Approximately one hydrogen atom per cubic meter is present in interstellar space. Assuming that the H – atom has a diameter of 10^{-10}m, the mean free path (m) approximately is

   (a) 10^{10} (b) 10^{19} (c) 10^{24} (d) 10^{14}

GATE 2011

6. For 1 mole of a monoatomic ideal gas, the relation between pressure (p), volume (V) and average molecular kinetic energy $(\bar{\varepsilon})$ is

   (a) $p = \frac{N_A\bar{\varepsilon}}{V}$ (b) $p = \frac{N_A\bar{\varepsilon}}{2V}$ (c) $p = \frac{2N_A\bar{\varepsilon}}{3V}$ (d) $p = \frac{2N_A}{3V\bar{\varepsilon}}$

GATE 2013

7. A 2 L vessel containing 2g of H_2 gas at 27ºC is connected to a 2L vessel containing 176 g of CO_2 gas at 27ºC. Assuming ideal behaviour of H_2 and CO_2, the partial pressure of H_2 at equilibrium is _______ bar.

GATE 2014

8. At a given temperature and pressure, the ratio of the average speed of hydrogen gas to that of helium gas is approximately _________

GASES

ANSWERS KEY

1. (a) 2. (a) 3. (b) 4. (b) 5. (b) 6. (c) 7. (6.2325)
8. (1.4. to.1.5)

QUANTA CHEMISTRY CLASSES
An institute of Chemical Sciences

15

ANALYTICAL

GATE 2005

1. One of the following is not related to polarography
(a) limiting current (b) diffusion current constant
(c) Ilkovic equation (d) current efficiency

2. A substance undergoes a two electron reversible reduction at dropping mercury electrode, and gives a diffusion current of 7.5 μA. When the potential at the dropping mercury electrode is –0.615 V, the current is 1.5 μA. The $E_{1/2}$ (in volt) will be
(a) –0.683 (b) –0.674 (c) – 0.652 (d) –0.633

3.

Column – I	**Column – II**
P. Ostwald process	I. Manufacture of nickel
Q. Solvay process	II. Manufacture of nitric acid
R. Mond process	III. Manufacture of Na_2CO_3
S. Frasch process	IV. Manufacture of silicones
	V. Manufacture of caustic soda
	VI. Mining of elemental sulfur

Codes:
(a) P – I, Q – III, R – II, S – VI (b) P – II, Q – III, R – I, S – VI
(c) P – II, Q – I, R – IV, S – V (d) P – III, Q – II, R – V, S – VI

GATE 2007

4. A student recorded a polarogram of 2.0 mM Cd^{2+} solution and forgot to add KCl solution. What type of error do you expect in his results?
(a) Only migration current will be observed
(b) Only diffusion current will be observed
(c) Both migration current as well as diffusion current will be observed
(d) Both catalytic current as well as diffusion current will be observed

GATE 2012

5. For the titration of a 10 mL (aq) solution of $CaCO_3$, 2mL of 0.001 M Na_2EDTA is required to reach the end point. The concentration of $CaCO_3$ (assume molecular weight of $CaCO_3 = 100$) is

(a) $5\times10^{-4}\,g/mL$ (b) $2\times10^{-4}\,g/mL$ (c) $5\times10^{-5}\,g/mL$ (d) $2\times10^{-5}\,g/mL$

ANALYTICAL

ANSWERS KEY

1.	(d)	2.	(d)	3.	(?)	4.	(?)	5.	(d)

16

LIQUID SOLUTION

GATE 2007

1. If the dipole moment of HCl is 1.08 D and the bond distance is 1.27Å, then partial charge on hydrogen and chlorine, respectively, are

(a) + 1.0 and –1.0 (b) + 0.85 and –0.85 (c) +0.356 and – 0.356 (d) +0.178 and – 0.178

GATE 2011

2. The freezing point constant for water is 1.86 K $(\text{mol kg}^{-1})^{-1}$. The change in freezing point when 0.01 mol glucose is added to 1 kg water is:

(a) 1.86 K (b) –1.86 K (c) 0.186 K (d) –0.0186 K

3. The activity of water at 11 bar and 298K is:

(a) 1.101 (b) 1.007 (c) 0.998 (d) 0.898

GATE 2012

4. If x_A and x_B are the respective mole fractions of A and B in a ideal solution of the two and T_A, T_B, T are the fusion temperatures of pure A, and pure B and the ideal solution respectively, then

(a) $1 - x_B = \exp\left[\frac{-\Delta H^0_{fus(B)}}{R}\left(\frac{1}{T} - \frac{1}{T_B}\right)\right]$

(b) $1 - x_B = \exp\left[\frac{\Delta H^0_{fus(B)}}{R}\left(\frac{1}{T} - \frac{1}{T_A}\right)\right]$

(c) $1 - x_B = \exp\left[\frac{\Delta H^0_{fus(B)}}{R}\left(\frac{1}{T} - \frac{1}{T_B}\right)\right]$

(d) $1 - x_B = \exp\left[\frac{-\Delta H^0_{fus(A)}}{R}\left(\frac{1}{T} - \frac{1}{T_A}\right)\right]$

LIQUID SOLUTION

ANSWER KEY

1. (?) 2. (d) 3. (a) 4. (d)